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# **SNOTEL WATER SUPPLY FORECAST AND INSTRUMENTATION DEVELOPMENT**

## **ARS-SCS COOPERATIVE STUDY**

Northwest Watershed Research Center  
Pacific West Area  
Agricultural Research Service  
U.S. Department of Agriculture  
Boise, Idaho

## **Annual Progress Report No. 7**

Cooperative Agreement No. 12-14-5700-0010

for FY 1987

To

Soil Conservation Service  
U.S. Department of Agriculture

**December 1, 1987**

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Department of  
Agriculture**



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## SNOTEL Water Supply Forecast and Instrumentation Development Study

### Personnel Involved:

K. R. Cooley,  
Hydrologist

Plan, conduct, and report on the simulated SNOTEL pressure transducer diurnal fluctuations.

A. L. Huber,  
Mathematician

Plan, conduct, and report on the existing SNOTEL pressure transducer diurnal fluctuations.

D. C. Robertson,  
Hydrologic Technician

Assist in planning and conducting the pressure transducer evaluations.

M. D. Burgess,  
Electronic Technician

Design, fabricate, test, and service any electronic instrumentation arising from this study.



## SNOTEL Water Supply Forecast and Instrumentation Development Study

### INTRODUCTION

Cooperative research between the SCS Water Supply Forecasting Group in Portland, Oregon and the Agricultural Research Service (ARS) Hydrologists in Boise, Idaho concentrated on three areas during fiscal year 1987. The major emphasis was to complete a study designed to determine the cause and magnitude of diurnal fluctuations in pressure transducer readings from SNOTEL precipitation gages during nonprecipitation periods. The research consisted of conducting a series of tests at the Boise Federal Building simulated SNOTEL site designed to provide an increased understanding of the system and fluid characteristics, and to evaluate possible techniques for alleviating problems at field sites. Tests were also continued at the field SNOTEL sites. First, data from all SNOTEL sites were obtained four times per day during a nine-day period in June 1987. These data were analyzed to identify those sites that exhibited diurnal fluctuations greater than allowed by design specifications. Twenty of the sites with large fluctuations were selected to receive new transducers that had been laboratory tested to establish pressure-temperature relationships. After installation of the new transducers, data from the SNOTEL sites were again obtained for analysis for a twelve-day period in October 1987.

A second study involved establishing a procedure for evaluating five different methods used by the various forecast centers for determining the reasonable maximum and reasonable minimum forecasts of streamflow. The objective was to evaluate the five different methods by comparing reasonable maximum and reasonable minimum statistics obtained by applying all five methods for seven different forecast points. The work completed for this year was limited to comparing the values obtained for one forecast point, the American Fork River near American Fork, Utah. This work will continue during the coming year.

A brief report describing field experience with several types of climatological sensors and data collections systems was also completed.

### OBJECTIVES

The objectives of the research conducted during fiscal year 1987, as outlined in the cooperative SCS-ARS workplan and amendments, are summarized as follows:

#### I. SNOTEL Precipitation Data Fluctuation Study

- A. Complete calculations of the magnitude of diurnal fluctuations considering temperature effects on the system, the fluid, and the transducer, for a variety of system configurations and fluids. Compare calculated fluctuations with those observed at the simulated SNOTEL site.

- B. Compare the performance of the same Robinson-Halpern pressure transducers at a field site and at the simulated SNOTEL site.
- C. Develop relationships between pressure and temperature for the SNOTEL sites and compare with previous relationships where possible. Use the correction equation developed to compare corrected and uncorrected values and demonstrate the magnitude of errors involved.

## II. Reasonable ~~Maximum~~-Reasonable Minimum Study

- A. Examine and evaluate five different methods of calculating reasonable maximum and reasonable minimum water supply forecasts to establish their comparability.

## III. Instrumentation Study

- A. Summarize field experience relating to climatological sensors, applicable for use at SNOTEL remote sites, gained from research at the Reynolds Creek Watershed, Idaho study site.

## Section I SNOTEL Precipitation Data Fluctuation Study

The reliability of precipitation gage readings from remote SNOTEL sites has been a concern to flood forecasters for several years. Diurnal fluctuations of over an inch have often been observed when precipitation did not occur. Indications of rainfall of this magnitude in a 12-hour period or less could affect flood forecasts drastically when snowpack conditions on a watershed are such that flooding could occur at any time. An initial analysis of precipitation gage readings from 517 remote sites showed that 60 percent exhibited a temperature dependency, and about 40 percent had diurnal fluctuations larger than specified in the pressure transducer design criteria. (See ARS-SCS Annual Progress Report No. 6, December 1986.) Because of these results, a more intensive study was initiated to 1) identify the problem, 2) develop correction equations, and 3) develop physical methods of correction.

### Review of Fiscal Year 1986 Studies

Data from the SNOTEL sites were analyzed for two periods in July and August 1986. The first analysis revealed that data would need to be collected at least four times per 24-hour period in order to establish relationships between temperature and pressure transducer readings. Data from the second period provided sufficient information to develop correction equations for each site based on temperatures observed. The analysis also showed that about 40 percent of the sites were exhibiting diurnal fluctuations in pressure transducer readings greater than what should have been recorded according to transducer design specifications. (See ARS-SCS Annual Progress Report No. 6, December 1986.)

Research at the simulated SNOTEL site conducted during fiscal year 1987 was designed to complement previous work. Selected tests were conducted using specific fluids to provide data for conditions not previously tested. Also, methods designed to reduce the diurnal fluctuations (based on results from last year's test) were tested as outlined in the objectives.

### Site Changes and Tests Conducted

Some minor changes were made on the simulated SNOTEL site prior to conducting tests during 1987. Changes to the system consisted of replacing the rubber hose and plastic pipe between the precipitation gage and the instrument shelter with a copper tube and adding a tygon tube manometer to the north side of the precipitation gage, thus simplifying the plumbing. These simplifications were justified based on last year's results, which indicated that the Robinson-Halpern\* pressure transducer responded well to rainfall

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\*Use of brand names is for reader convenience and does not constitute endorsement by the U.S. Department of Agriculture, Agricultural Research Service.

measured by the Bureau of Reclamation recording raingage at the site. Also, the pressure traces produced by the Robinson-Halpern transducer and two Druck transducers were essentially the same, thus the two extra transducers and the extra plastic pipe were not required. Other changes involved relocation and addition of temperature sensors.

The number of temperature sensors in the gage was reduced from 5 to 3, and they were placed so that the lowest would always be in the fluid, the highest would always be above the fluid, and the middle one would be in or above the fluid, depending upon the amount of fluid in the gage. Four new temperature sensors were attached to the exterior surface of the gage so that a north-facing and a south-facing pair of sensors would be above fluid level, and a pair of sensors would be measuring exterior gage surface temperature within the depth of the fluid. A new temperature sensor was placed in the precipitation gage chamber underneath the fluid and above the ground surface. Temperature sensors were also placed on the copper tubing 12 to 14 inches below the ground surface, between the gage and the shelter (Fig. 1).

Air temperature and precipitation were monitored on recording equipment existing at the site. All of the data were recorded at 15-minute intervals throughout the study period. In addition, manometer readings were made near the time of maximum and minimum air temperature on most days during the study period.

Fifteen test periods were selected for study analysis. The conditions imposed on the system, the fluid level, fluid characteristics, average change in manometer level, and average daily temperature change are shown in Table 1 for one day during each of these periods.

## Results

### A. Simulated SNOTEL Site Studies

Tests conducted at the Boise simulated SNOTEL site were designed to augment last year's results, and to provide additional information about the fluids and the system. Figures 2 through 16, which show variations in pressure and temperature for 15 different 3-day study periods, indicate that responses to valve settings and fluid characteristics are similar to those obtained last year. For example, closing the valve at the base of the gage (Fig. 1) changed the relationship between temperature and pressure from inverse to direct (Fig. 2 vs. Fig. 4). Also, the magnitude of the diurnal pressure fluctuation diminished as the concentration of methyl-alcohol and ethylene-glycol (commonly called Glyco-Meth) in the mixture decreased (as percent water increased) as shown in Figures 2, 5, and 6.

Further study of Figures 2-16 indicates that temperature effects on the electronic data recording equipment are negligible, since the magnitude and timing of the fluctuations can be changed simply by opening and closing the valves, while all other factors remain the same. Changes in fluid characteristics also change the magnitude of the fluctuations while all else remains the same. Further evidence that the electronic package was not affected significantly by temperature was obtained when a completely different type of data acquisition system was installed.

SIMULATED "SNOTEL" SITE  
LOCATED  
AT THE BOISE FEDERAL BUILDING

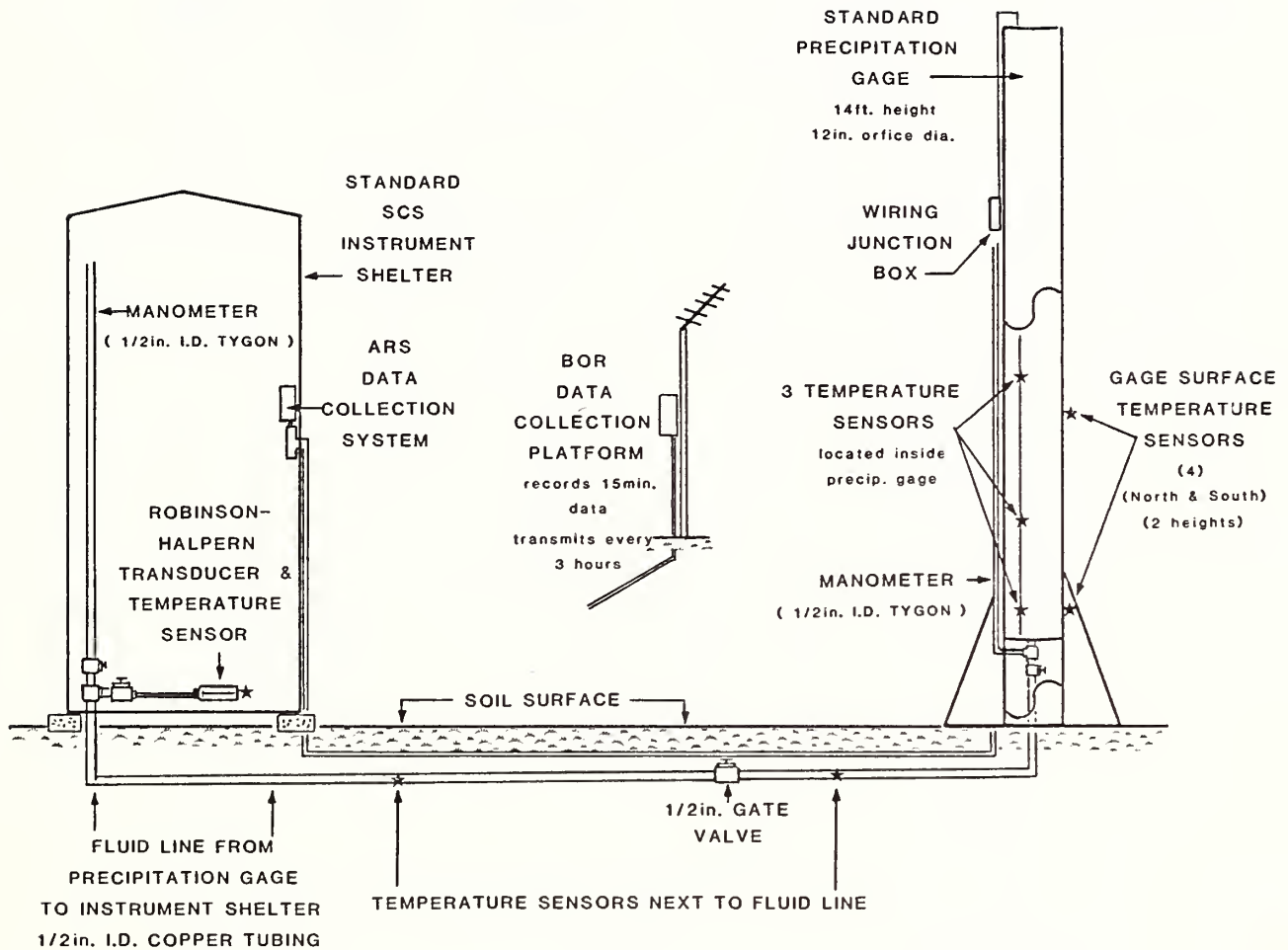


Figure 1. Schematic diagram of the Boise Federal Building simulated SNOTEL site showing location of system components and sensor.

Table 1. Conditions imposed on the simulated remote precipitation gage system, during 15 periods studied, fluid level and characteristics, observed fluid level changes, and average daily temperature changes.

Date (1987) & (Julian Day)	Fluid Type	Depth of Fluid in Precip. Gage (inches)	System Configuration	Average Daily Change in Manometer Reading (inches)	Average Daily Change in Air Temp. (°F)
6-13 (164)	95% glyco-meth 5% water	10.5	Open	0.19	41.6
6-25 (176)	95% glyco-meth 5% water	10.5	Line valve closed	0.56	44.0
6-27 (178)	95% glyco-meth 5% water	10.5	Gage valve closed	0.75	36.1
7-3 (184)	30% glyco-meth 70% water	30.5	Open	0.72	34.9
7-7 (188)	18% glyco-meth 82% water	50.5	Open	0.94	30.8
7-13 (194)	18% glyco-meth 82% water	50.5	Line valve closed	0.75	41.7
7-15 (196)	18% glyco-meth 82% water	50.5	Open - galvanized shield	0.41	44.7
7-26 (207)	18% glyco-meth 82% water	50.5	Open - brown shield	1.44	45.0
8-4 (216)	100% ethylene- glycol	10.0	Open	0.19	49.9
8-8 (220)	100% ethylene- glycol	10.0	Closed	0.31	42.5
8-11 (223)	40% methanol 60% water	13.0	Open	0.13	34.3
8-18 (230)	100% glyco-meth	10.0	Open	-0.09	46.0
8-24 (236)	100% glyco-meth	10.0	Open - white paint	0.06	35.7
9-2 (245)	100% glyco-meth	10.0	Open - brown paint	0.03	27.1
9-13 (256)	100% glyco-meth	10.0	Open - brown paint	--	41.6

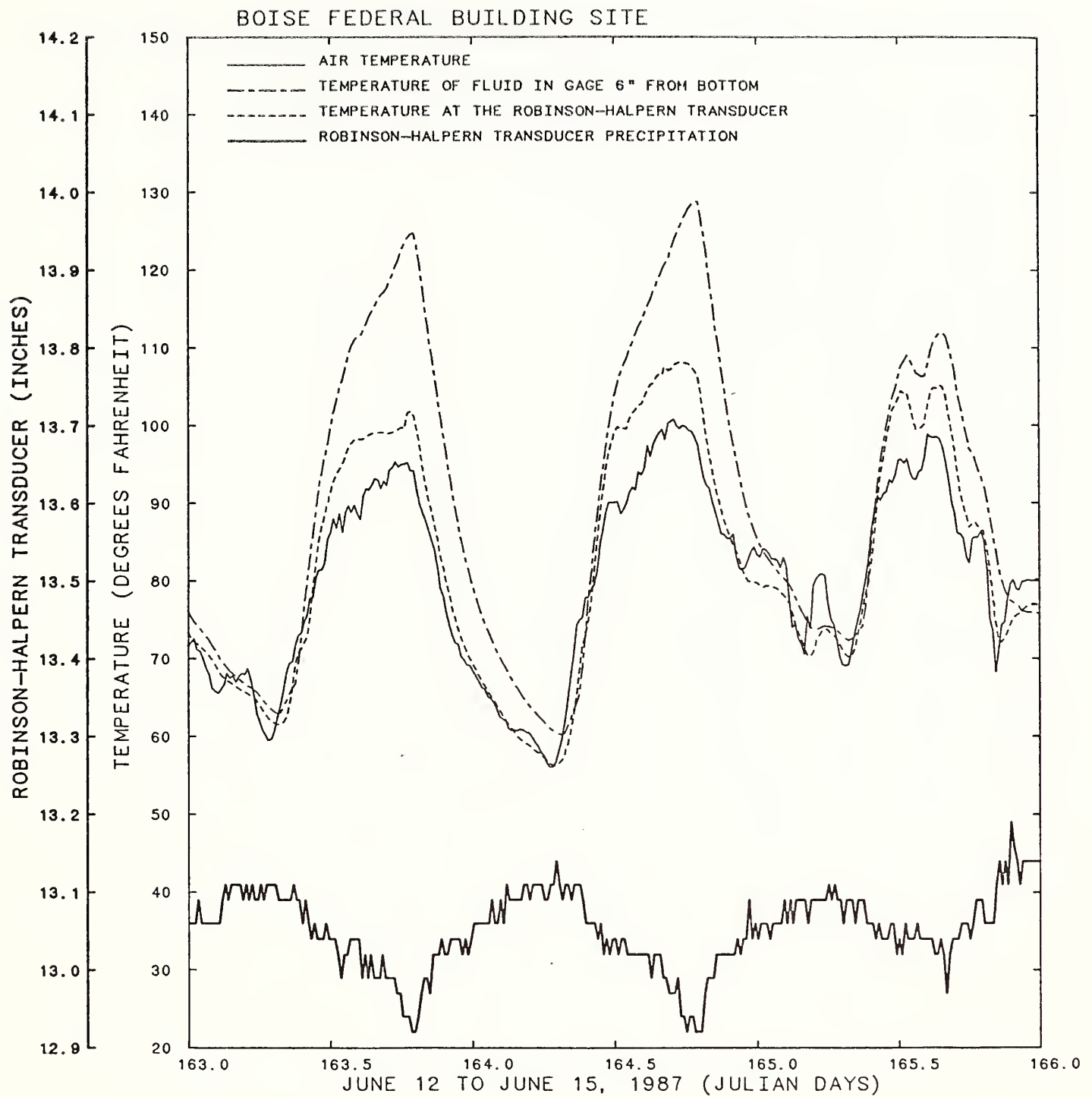


Figure 2. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 95% Glyco-Meth - 10.5 inch fluid depth, June 12 to June 15, 1987.

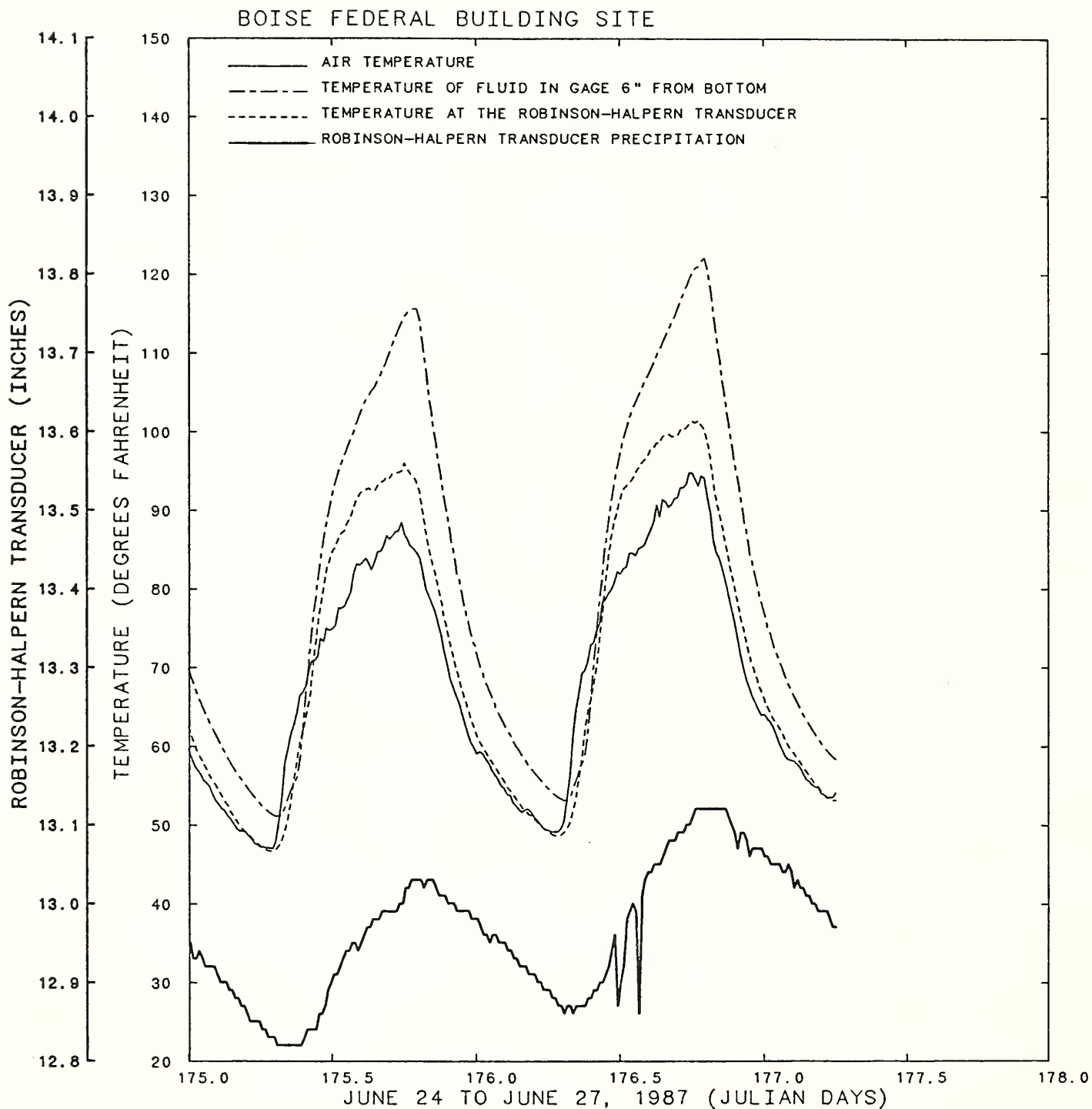


Figure 3. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. Line valve closed - 95% Glyco-Meth - 10.5 inch fluid depth, June 24 to June 27, 1987.

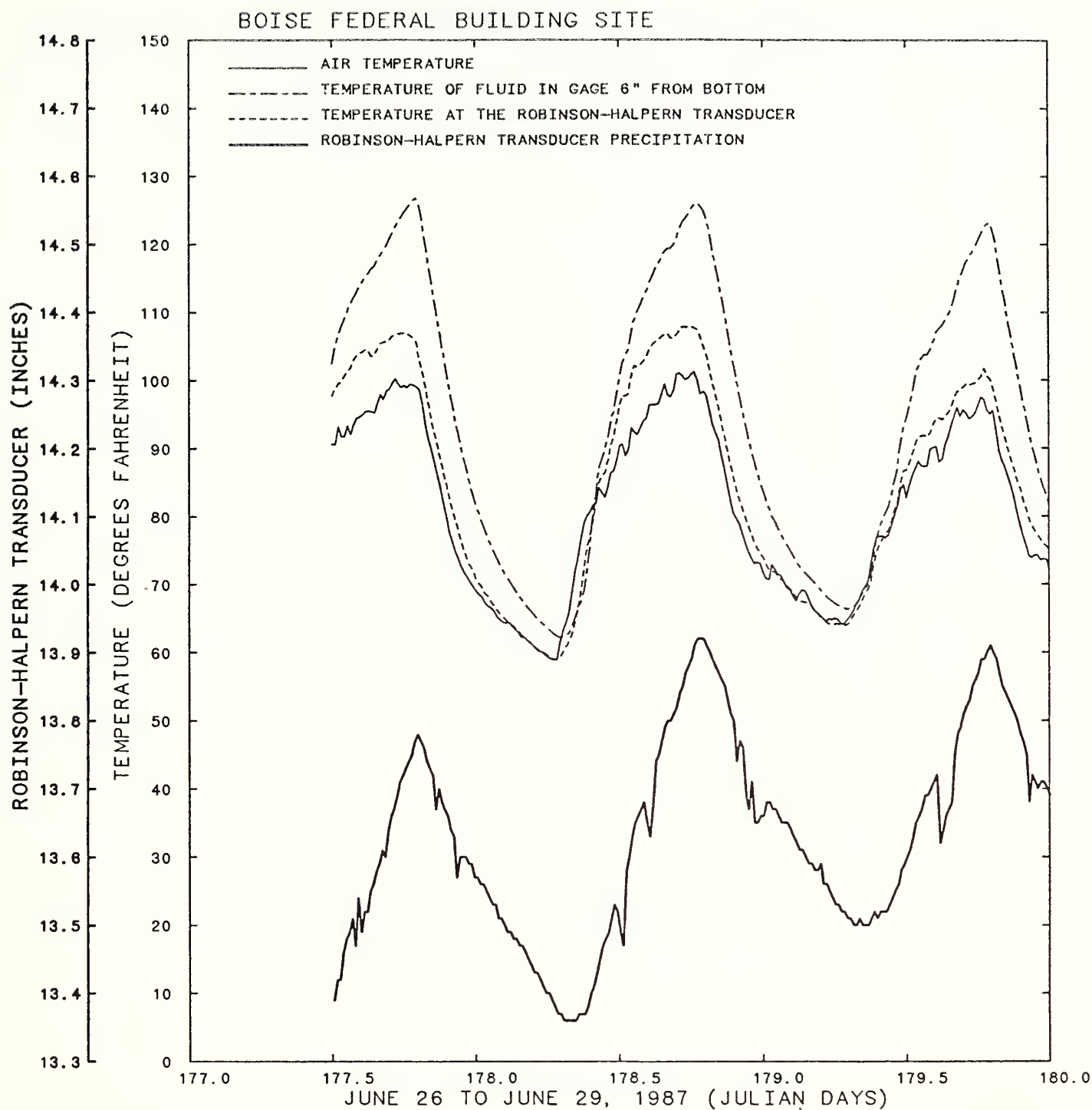


Figure 4. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. Gage valve closed - 95% Glyco-Meth - 10.5 inch fluid depth, June 26 to June 29, 1987.

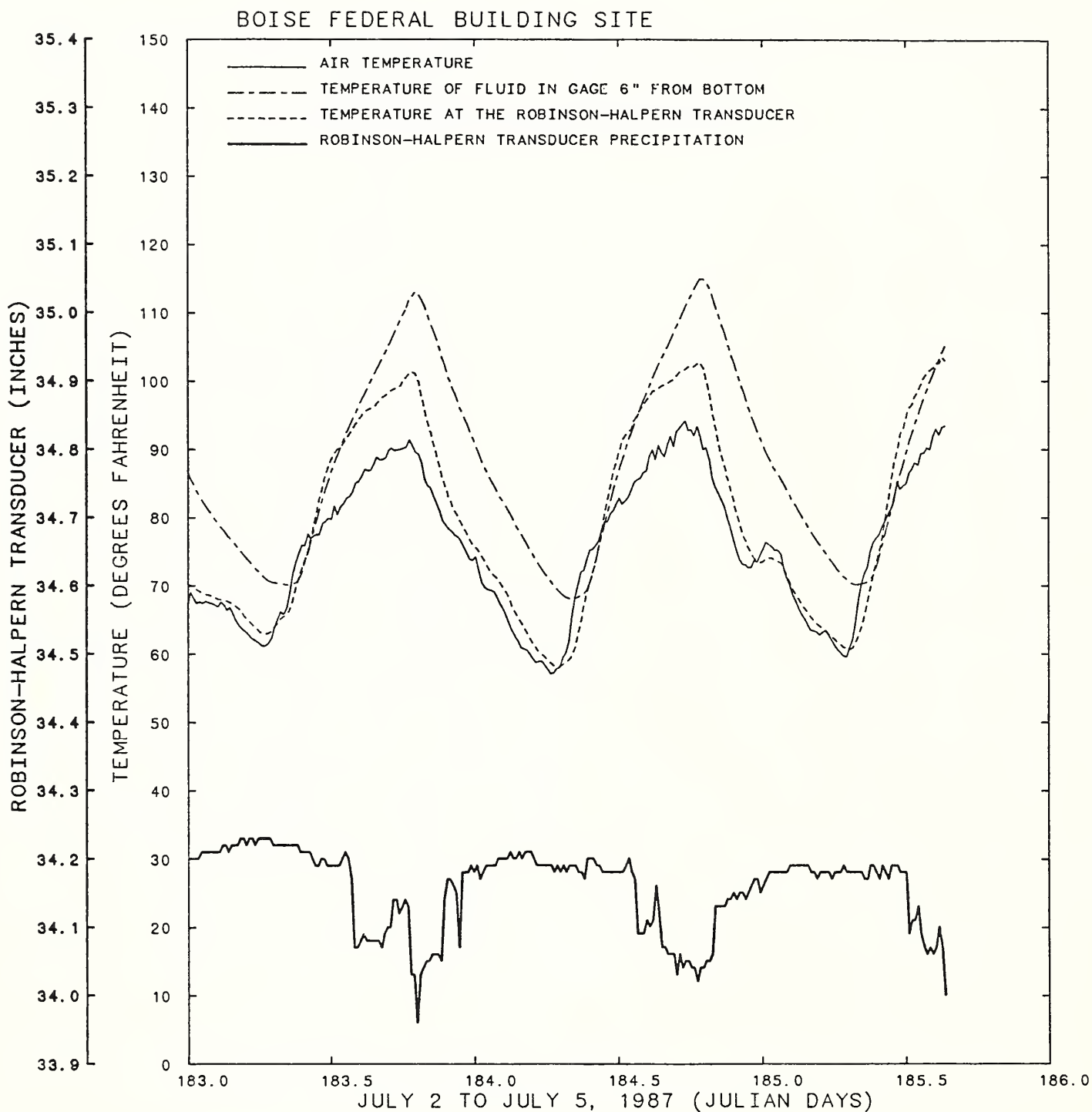


Figure 5. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 30% Glyco-Meth - 31.0 inch fluid depth, July 2 to July 5, 1987.

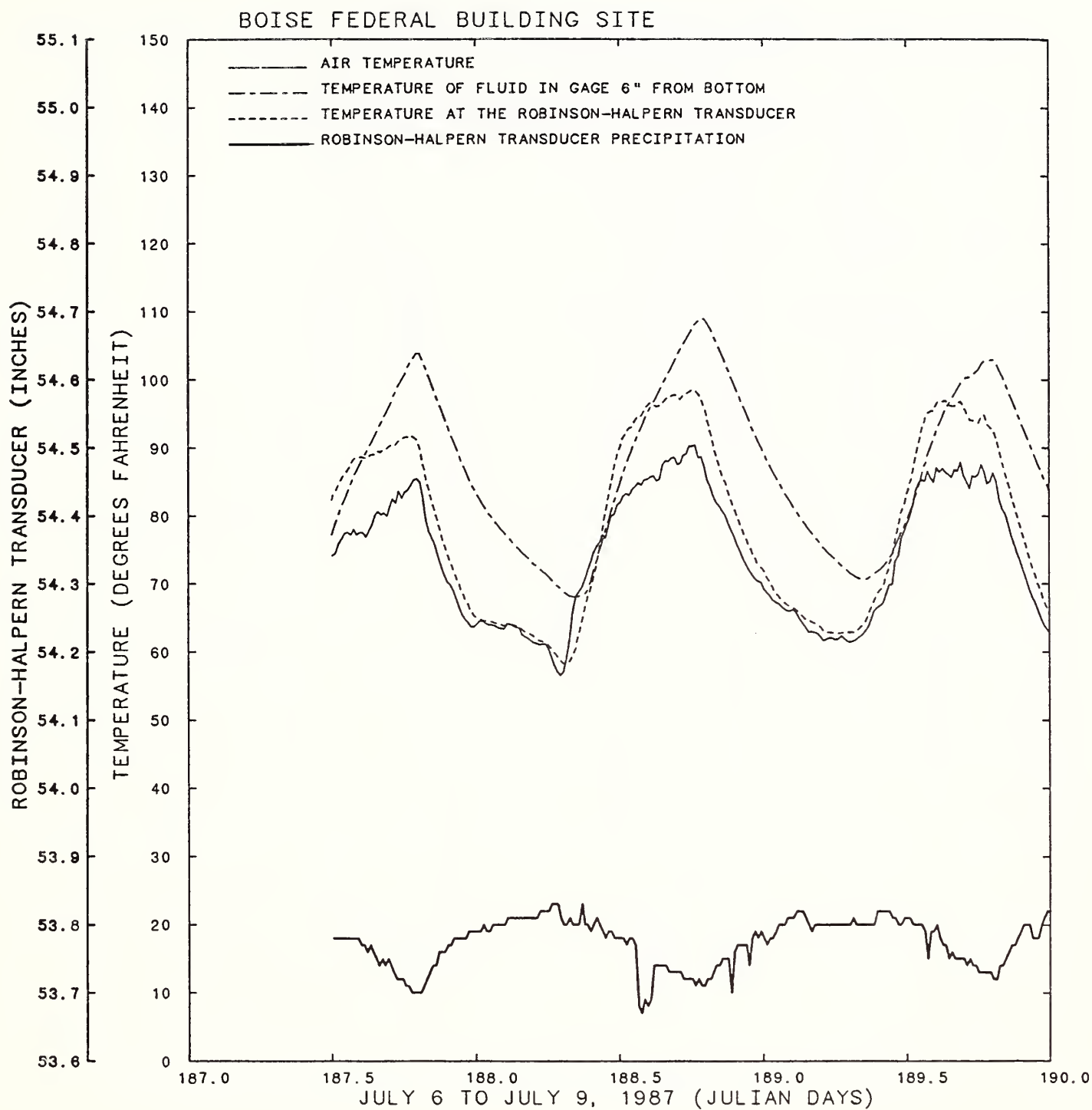


Figure 6. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 18% Glyco-Meth - 51.5 inch fluid depth, July 6 to July 9, 1987.

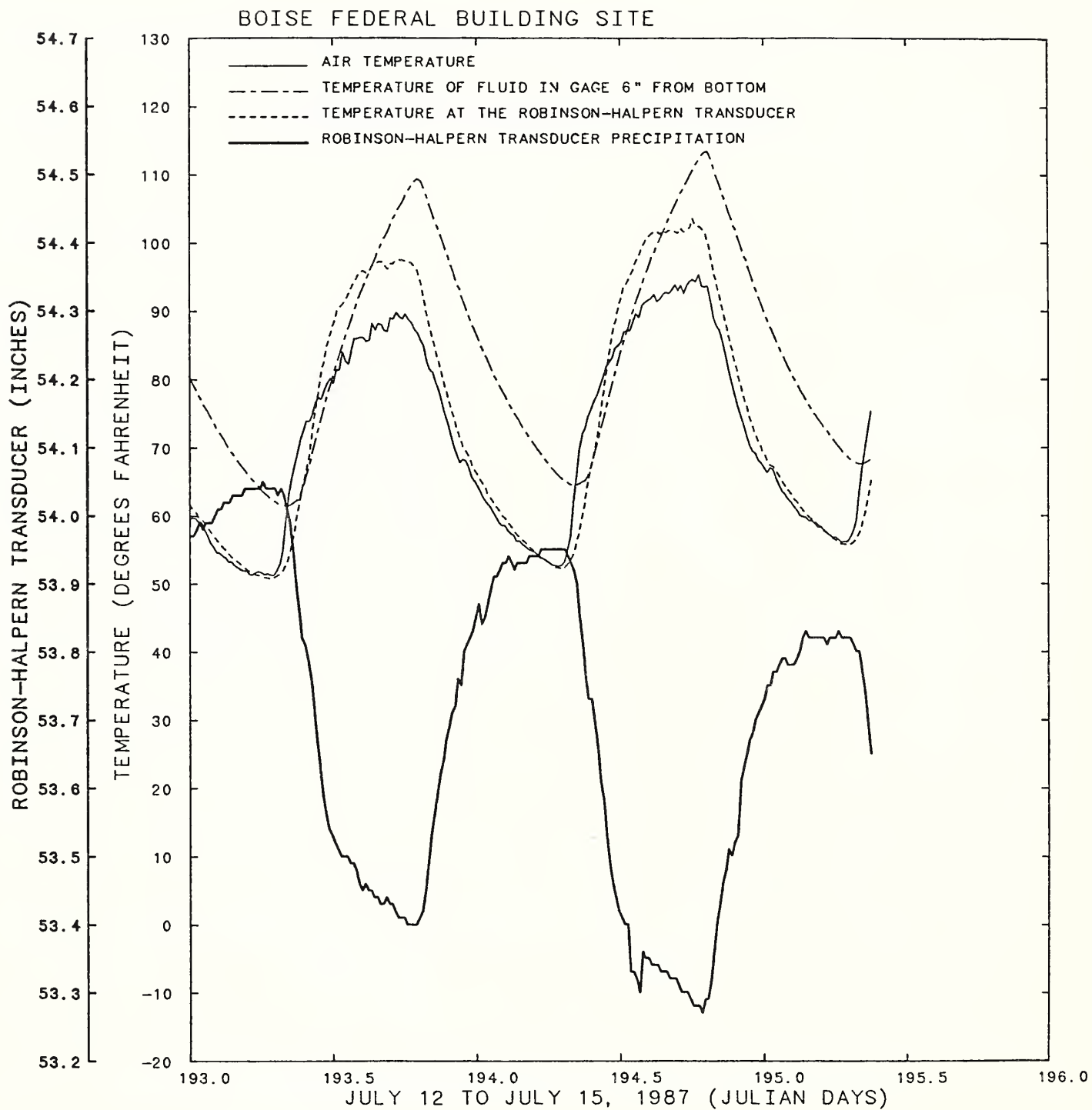


Figure 7. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. Line valve closed - 18% Glyco-Meth - 51.5 inch fluid depth, July 12 to July 15, 1987.

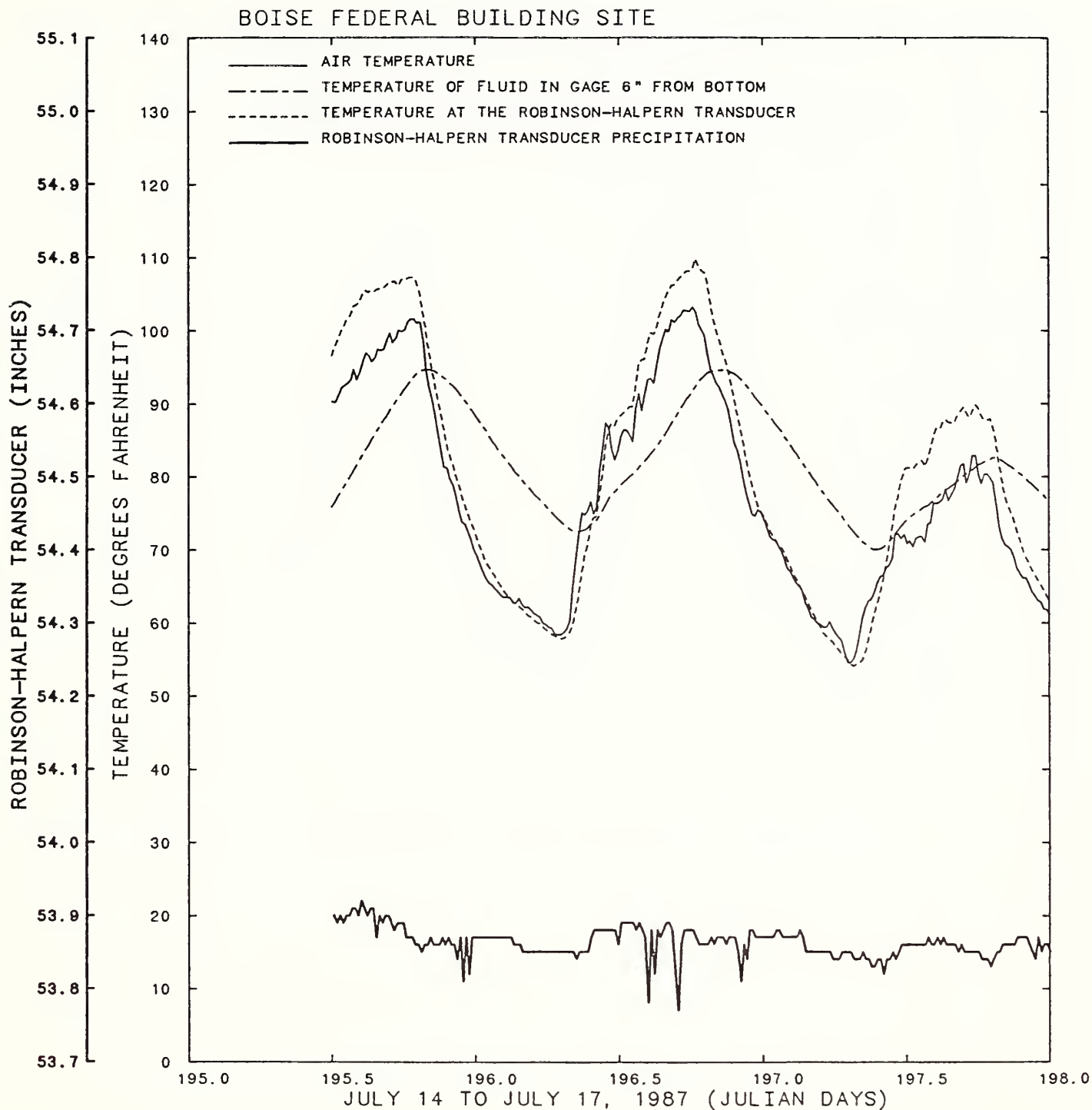


Figure 8. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 18% Glyco-Meth - 51.5 inch fluid depth - galvanized shield, July 14 to July 17, 1987.

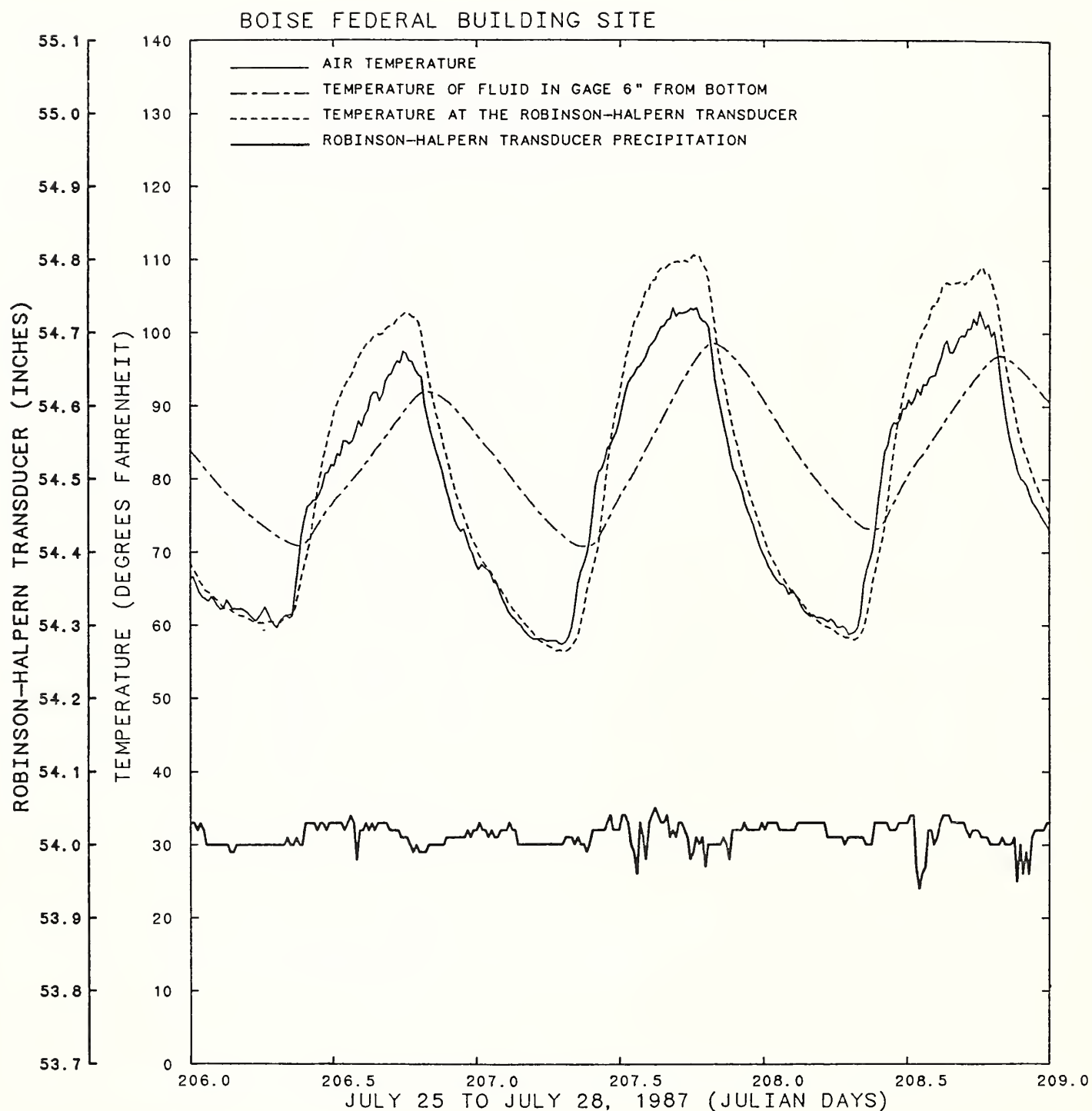


Figure 9. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 18% Glyco-Meth - 51.5 inch fluid depth - brown shield, July 25 to July 28, 1987.

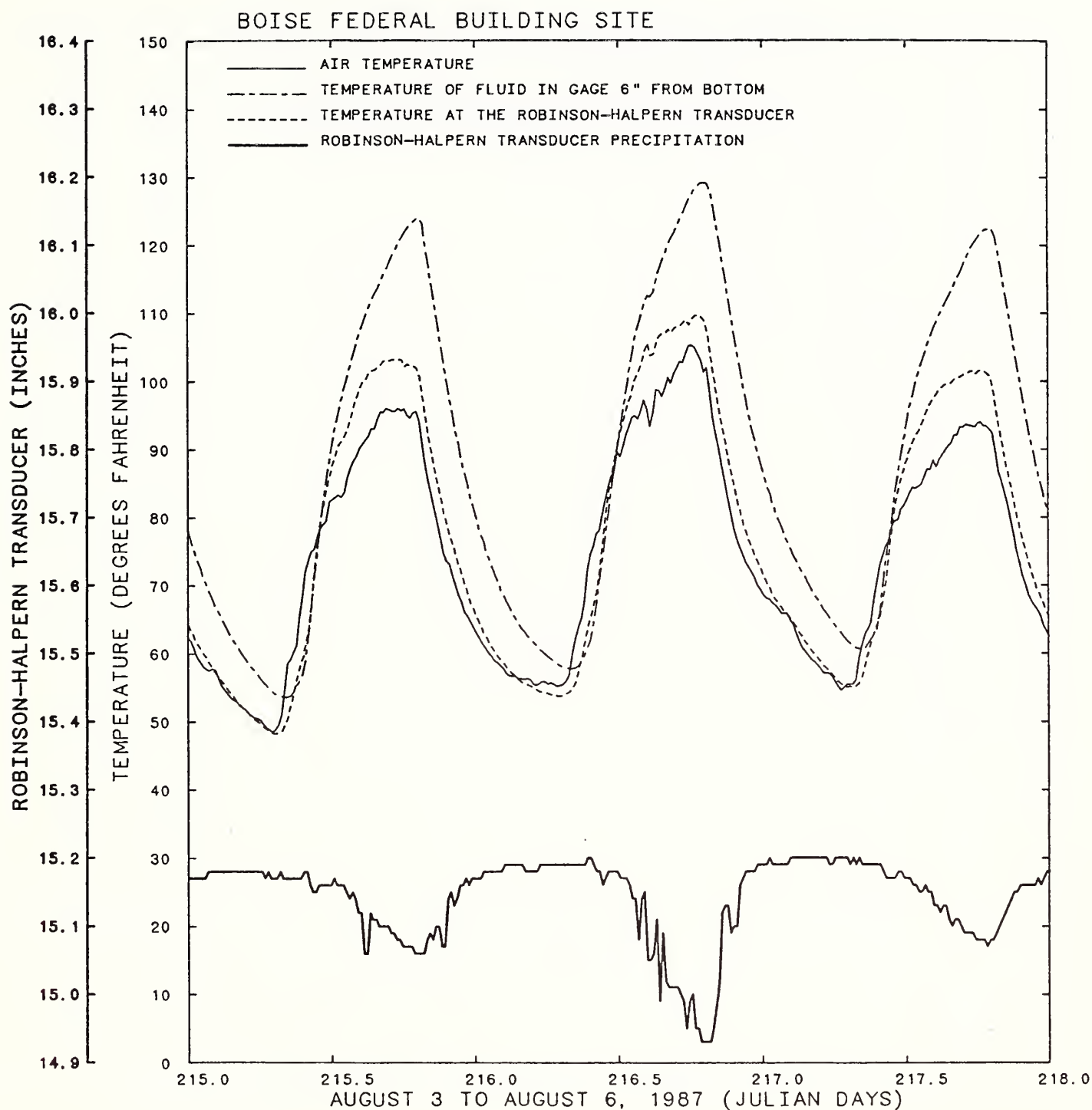


Figure 10. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 100% Ethylene Glycol - 12.0 inch fluid depth, August 3 to August 6, 1987.

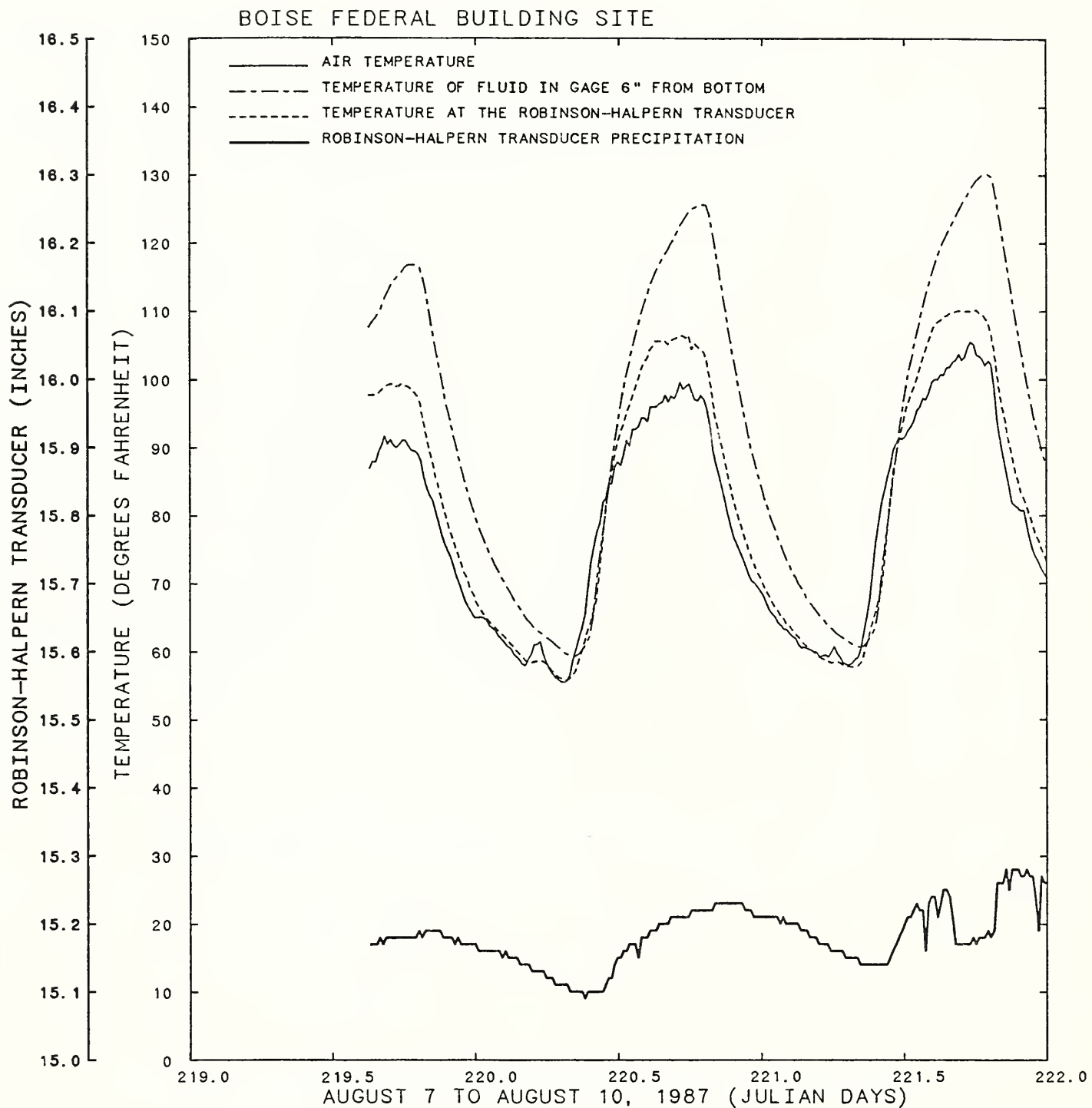


Figure 11. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. Line valve closed - 100% Ethylene Glycol - 12.0 inch fluid depth, August 7 to August 10, 1987.

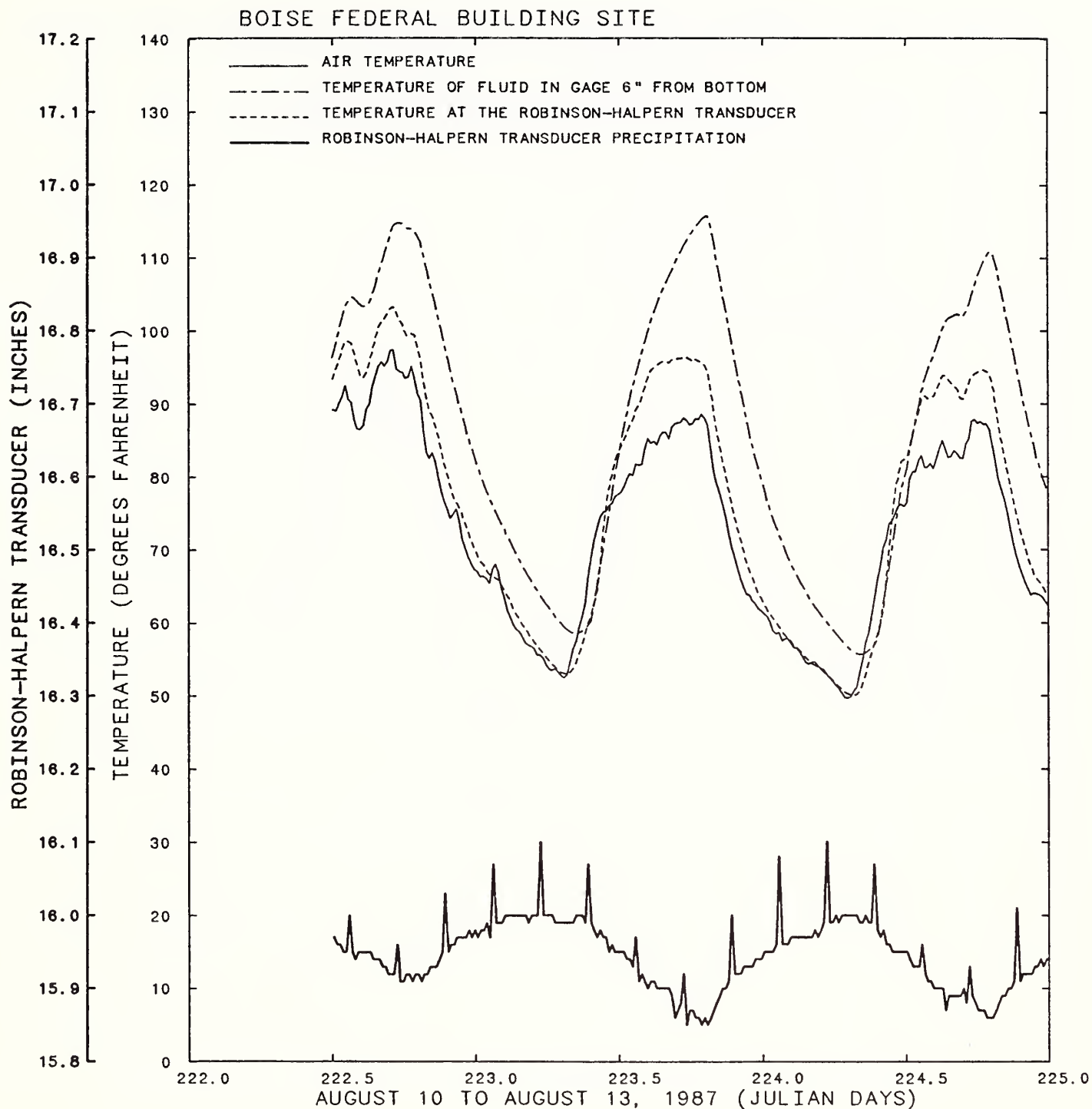


Figure 12. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 40% Methanol and 60% water - 13.0 inch fluid depth, August 10 to August 13, 1987.

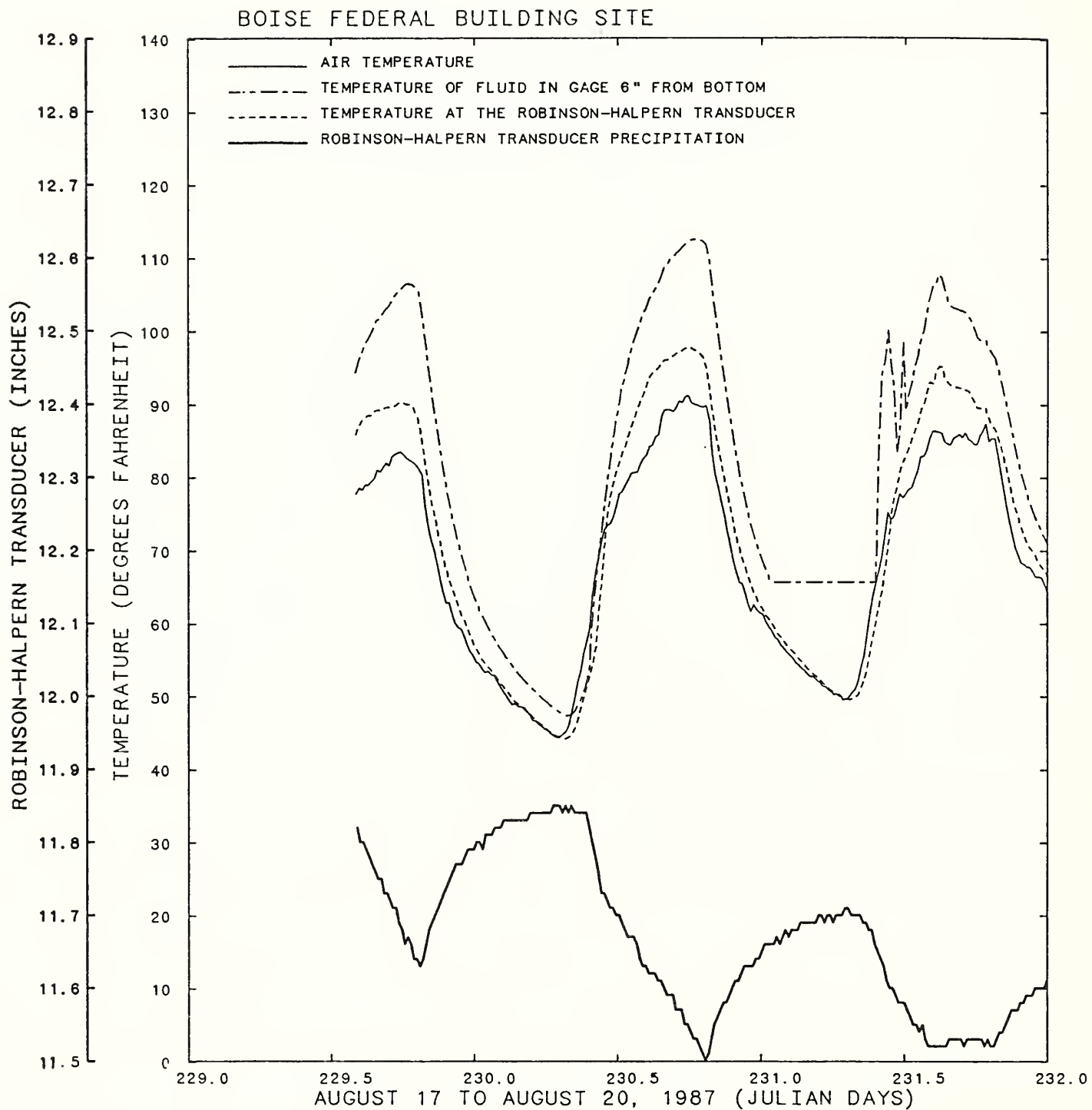


Figure 13. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 100% Glyco-Meth - 8.5 inch fluid depth, August 17 to August 20, 1987.

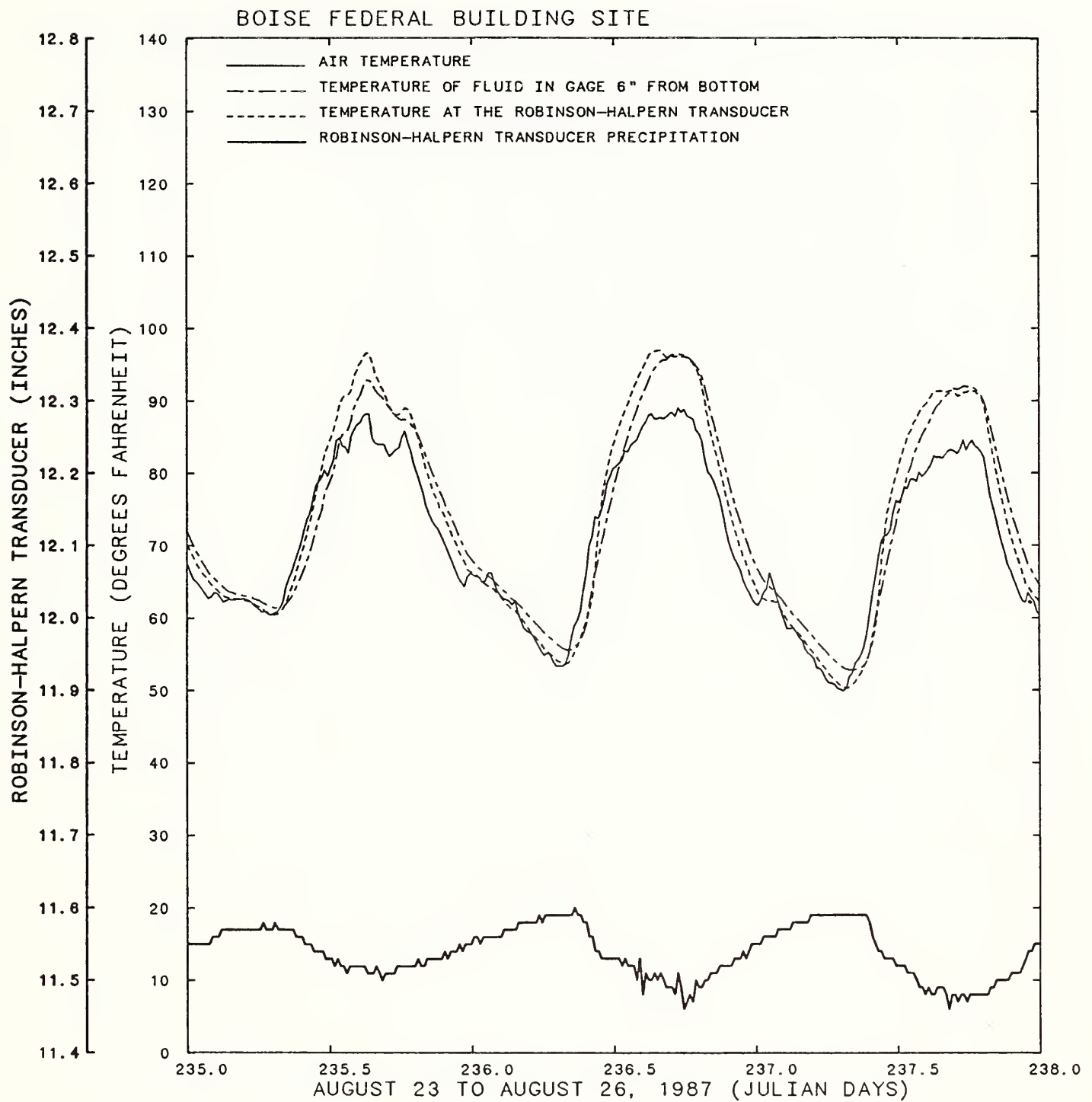


Figure 14. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 100% Glyco-Meth - 8.5 inch fluid depth - gage painted white, August 23 to August 26, 1987.

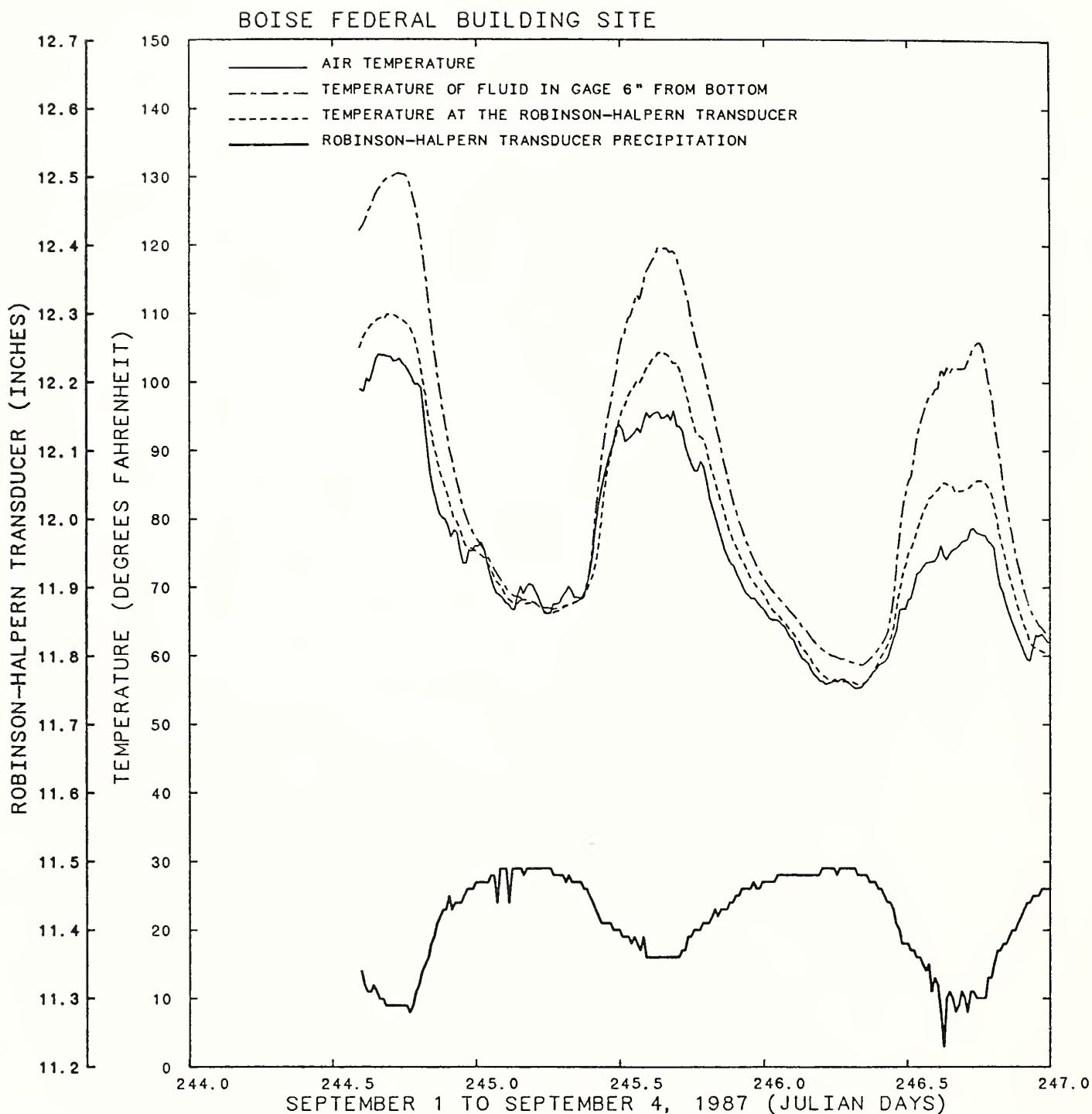


Figure 15. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 100% Glyco-Meth - 8.5 inch fluid depth - gage painted brown, September 1 to September 4, 1987.

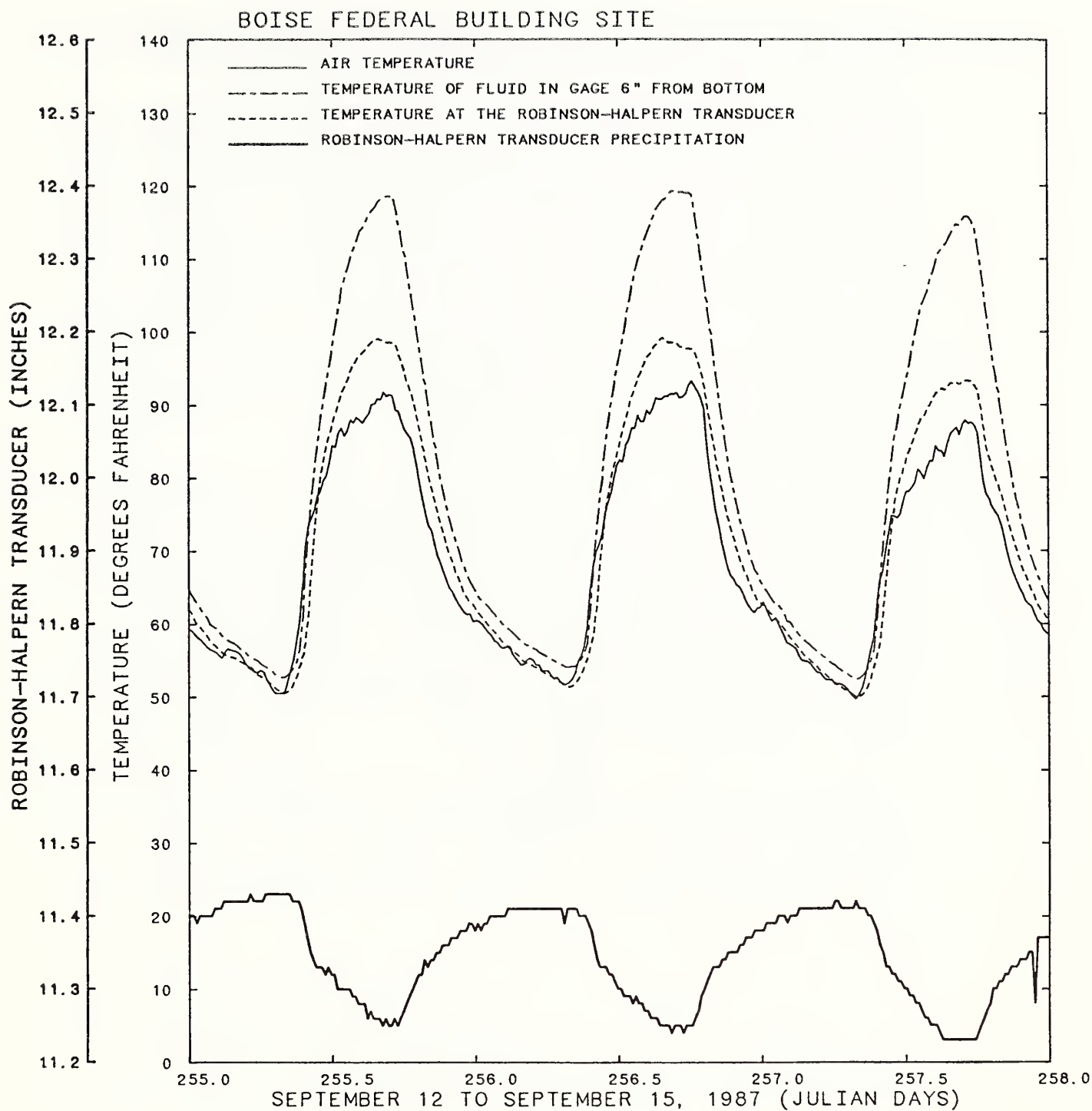


Figure 16. Temperature and pressure transducer records from the simulated SNOTEL site near the Boise Federal Building. All valves open - 100% Glyco-Meth - 8.5 inch fluid depth - gage painted brown, September 12 to September 15, 1987.

On June 15, 1987 the Bureau of Reclamation Data Platform (DCP) was replaced by an Omni Data acquisition system (DAS) with no discernable changes in pressure patterns or magnitudes being observed.

Another interesting feature shown in the figures is the effect on the transducer response brought about by changes at the precipitation gage. For example, alterations that changed the thermal regime of the gage, such as an insulating paint, shielding, or insulation (used last year), reduced the diurnal fluctuation considerably (Figs. 2, 8, 9, 13, 14, 15, 16). The shielding consisted of a sheet metal cylinder about 5 inches in radius larger than the precipitation gage, which covered all but approximately 16 inches at the top and bottom, thus allowing air to circulate between the two. The insulating paint is a flexible coating containing small ceramic insulating beads which is being used on SCS SNOTEL instrument shelters in Idaho. Both white and brown colors were used in the tests, and references to white or brown in the discussions, figures, or tables refer to this paint rather than the standard brown paint normally used to paint the precipitation gages.

The effects of shielding and insulating paint on the thermal regime of the precipitation gage and the fluid in the gage are seen in Figures 17-21. These figures show the relationship between air temperature, fluid temperature 6 inches above the bottom of the fluid, and the outer surface skin temperature of the gage on the north and south sides at the fluid level. Figure 17 shows the temperature relationships for a standard gage configuration. Note that the fluid and gage temperatures are about the same as air temperature during the early mornings when minimum temperatures occur. In the afternoons, however, when maximum temperatures occur, fluid and gage temperatures are considerably higher than air temperature (as much as 30 °C).

Figures 18 and 19 show the same temperatures when the gage was shielded. In this case, the fluid and gage temperatures experience a diurnal range in temperature less than air temperature, being both cooler in the afternoons and warmer in the mornings. The color of the shield does not seem to make any difference in temperature relationships, indicating that the insulating effects and air movement between the gage and the shield are the important features.

After removing the shield, the gage was painted white, using an insulating paint (Figure 20). Gage and fluid temperatures are similar to air temperature under these conditions, except for a few hours during the afternoon when they are somewhat higher (about 10 °C). The insulating value of the paint appears to be minimal in this application however, since the temperature relationships were similar to those shown in Figure 17 when the gage was painted brown even though the insulating paint was again used (Figure 21). The white color was therefore responsible for the reduced fluid and gage temperatures noted in Figure 20, because of its reflective properties.

Calculations of the expected change in pressure due to temperature effects on the transducer, and expansion of the system are presented in Tables 2 and 3 for 36 different study periods conducted during the past two years at the Boise simulated SNOTEL site. These calculations

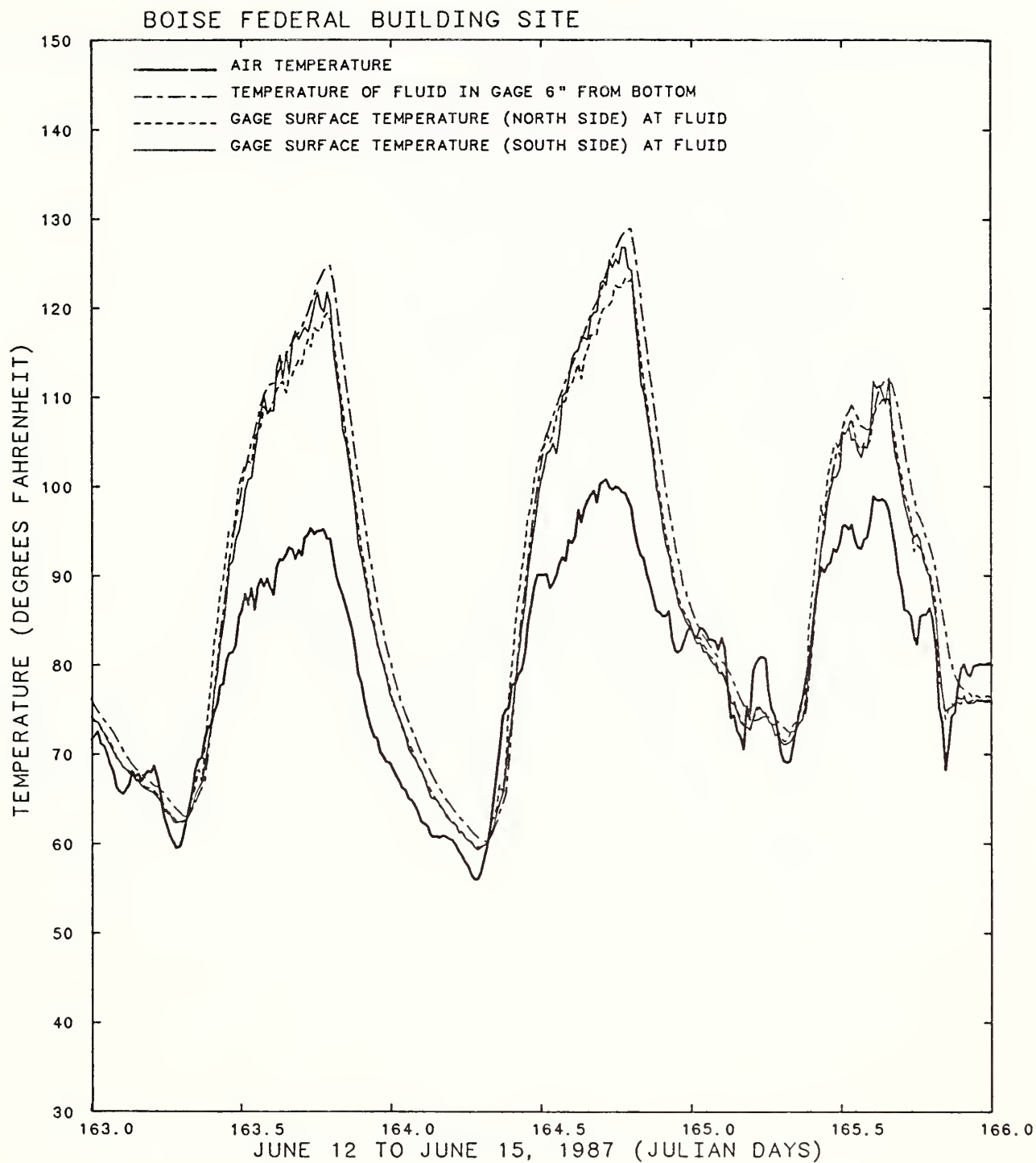


Figure 17. Temperature records from the simulated SNOTEL site near the Boise Federal Building - standard precipitation gage, June 12 to June 15, 1987.

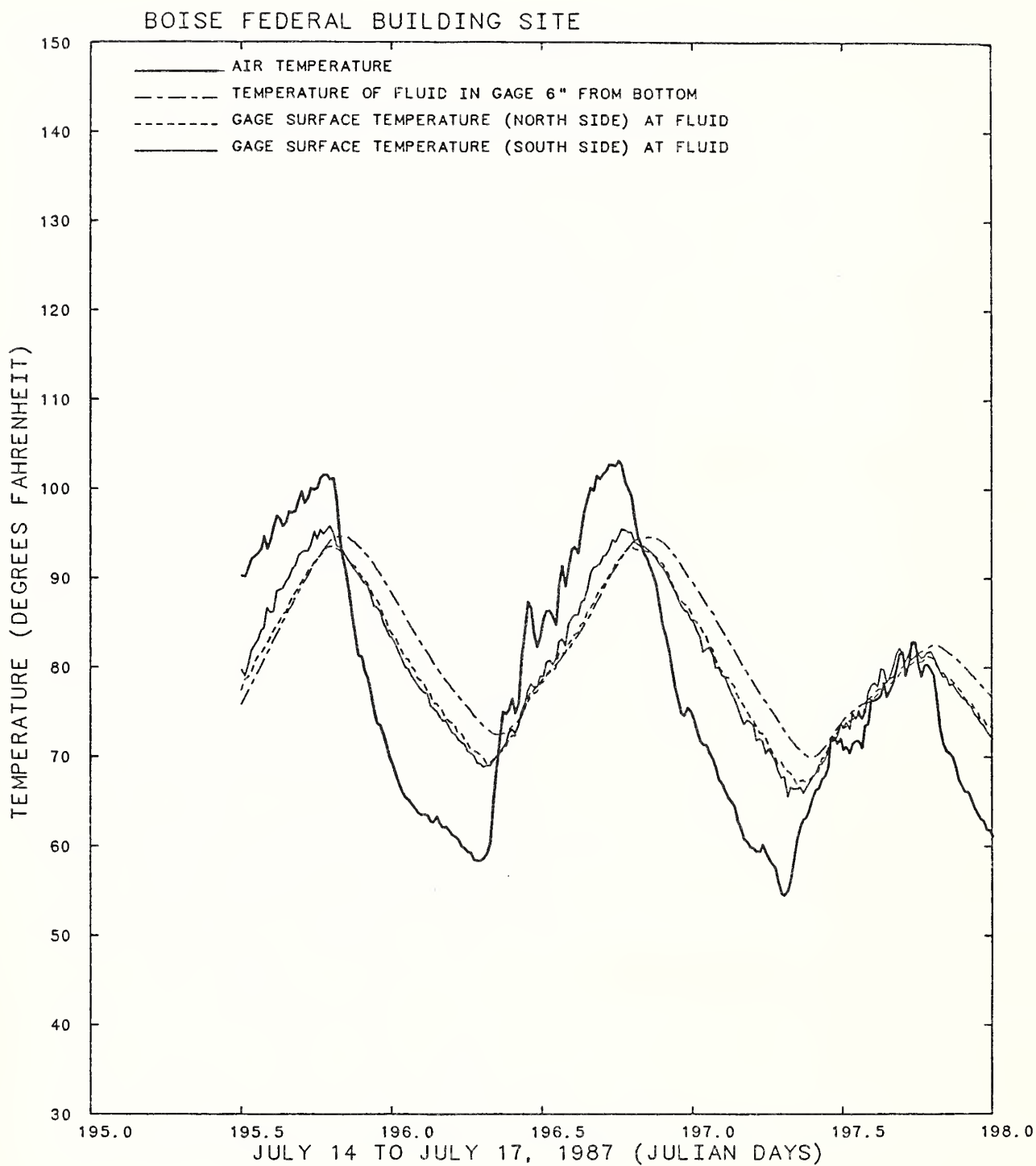


Figure 18. Temperature records from the simulated SNOTEL site near the Boise Federal Building - galvanized shielded gage, July 14 to July 17, 1987.

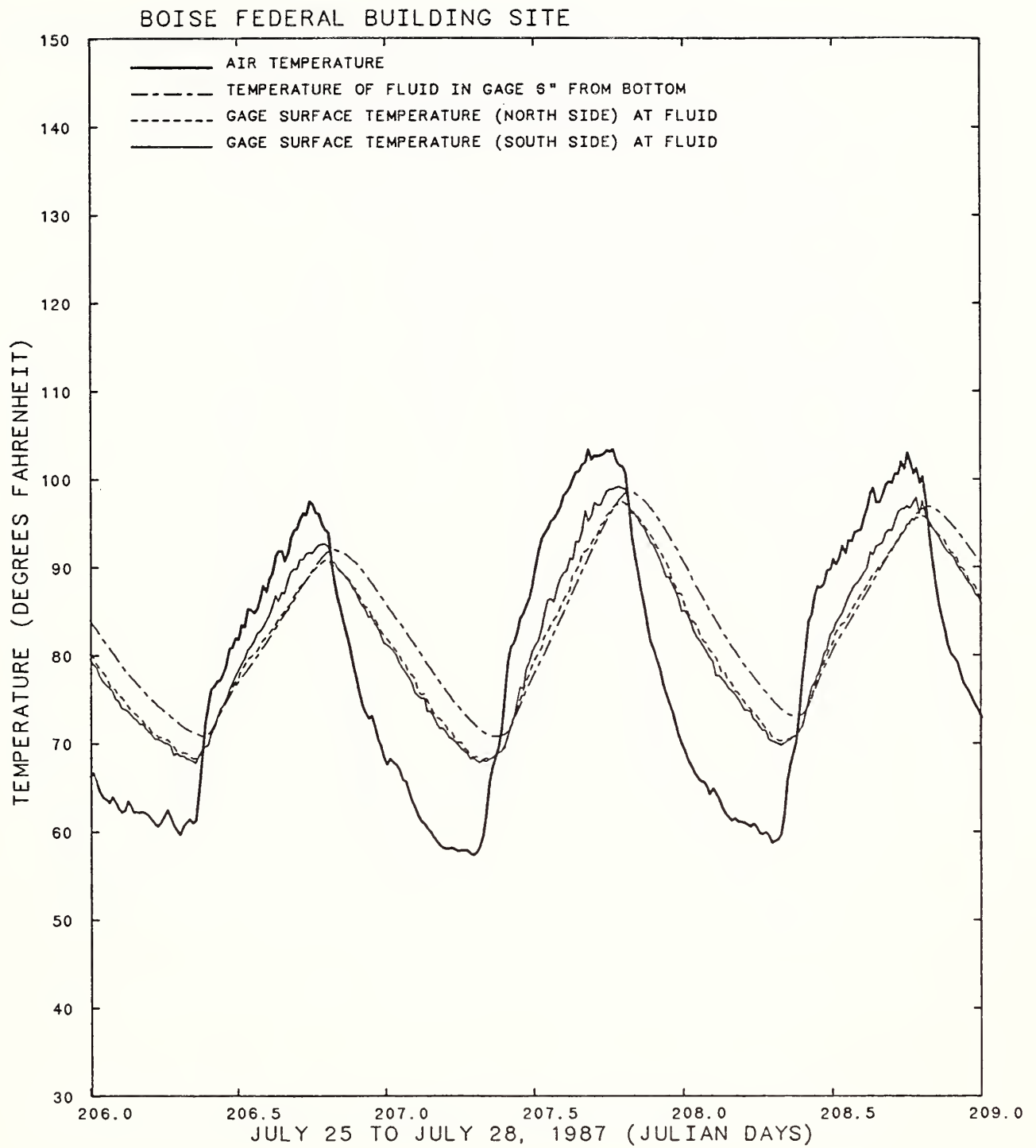


Figure 19. Temperature records from the simulated SNOTEL site near the Boise Federal Building - brown shielded gage, July 25 to July 28, 1987.

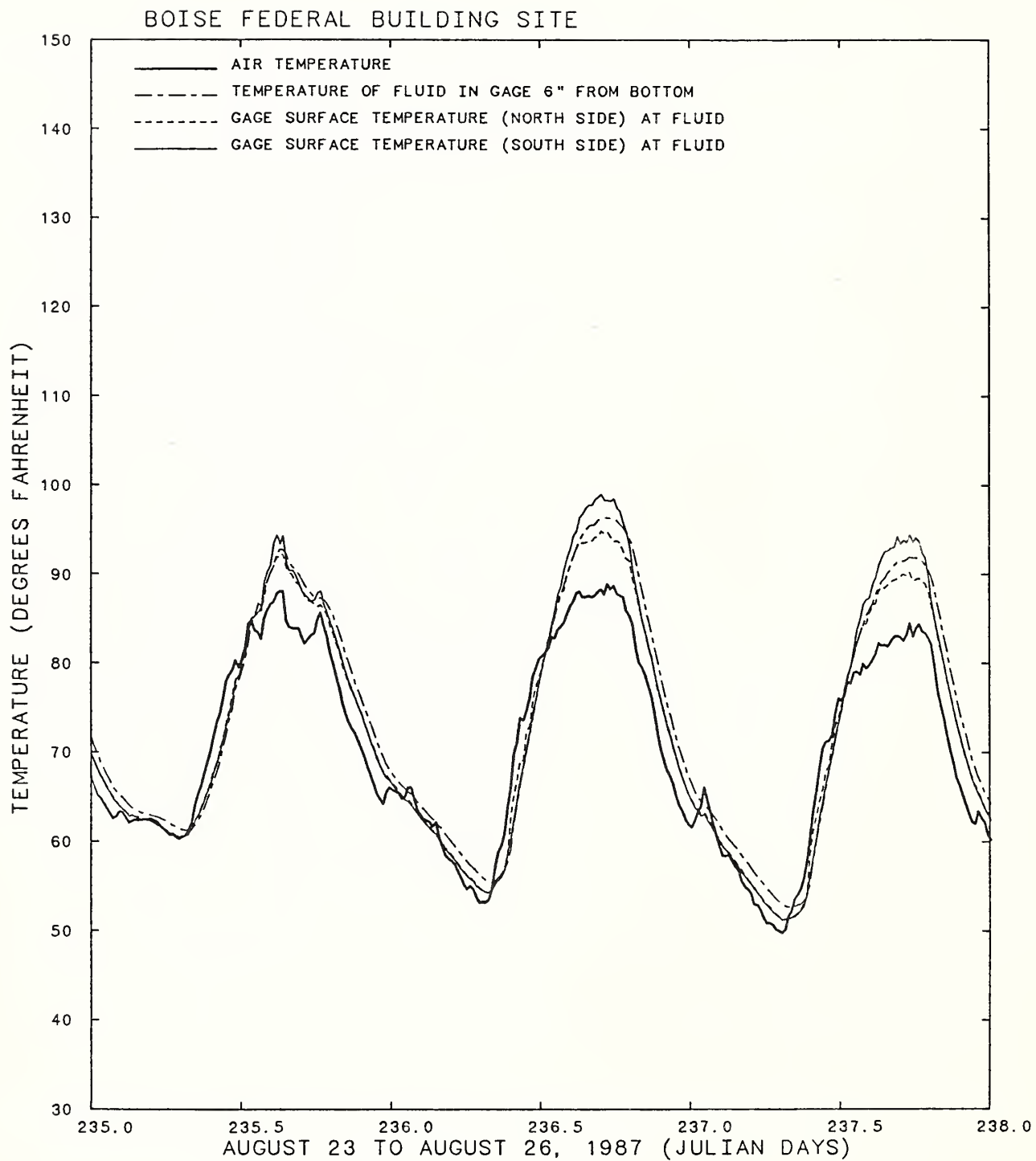


Figure 20. Temperature records from the simulated SNOTEL site near the Boise Federal Building - white insulating paint on gage, August 23 to August 26, 1987.

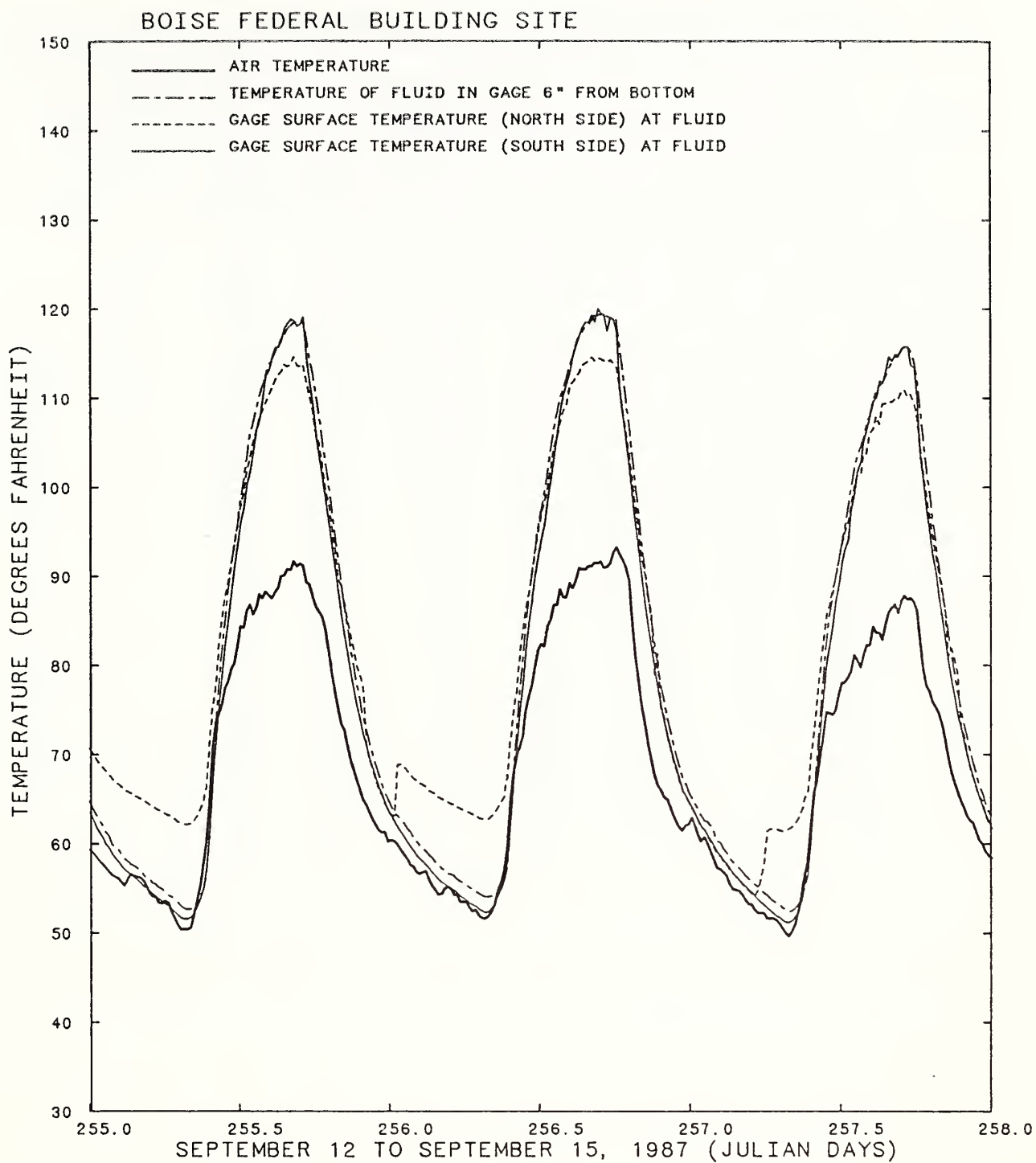


Figure 21. Temperature records from the simulated SNOTEL site near the Boise Federal Building - brown insulating paint on gage, September 12 to September 15, 1987.

Table 2. Comparison of observed and calculated diurnal pressure changes for a simulated remote precipitation gage system in Boise, Idaho. All valves are open.

Date & (Julian Day)	Percent Methyl-Glycol in Mixture	Fluid Depth (inches)	Pressure Change (inches of water)					Remarks
			Computed	Transducer		Observed	Difference	
				Correction	Total			
			<u>1/</u>	<u>2/</u>	<u>3/</u>	<u>4/</u>	<u>5/</u>	
6-10-86 (161)	100	9.0	-.03	-.12	-.15	-.37	-.22	
9-15-86 (258)	100	9.0	-.02	-.08	-.10	-.30	-.20	
9-23-86 (266)	100	9.0	-.03	-.12	-.15	-.32	-.17	
8-18-87 (230)	100	8.5	-.02	+.11	+.09	-.30	-.39	
8-24-87 (236)	100	8.5	-.01	+.08	+.07	-.13	-.20	Painted white
9-2-87 (245)	100	8.5	-.02	+.07	+.06	-.13	-.19	Painted brown
9-13-87 (256)	100	8.5	-.02	+.10	+.08	-.16	-.24	Painted brown
6-13-87 (164)	95	10.5	-.03	+.10	+.07	-.22	-.29	
10-13-86 (286)	85	11.0	-.03	-.12	-.15	-.25	-.10	
10-29-86 (302)	85	11.0	-.03	+1.16	+1.13	+.56	-.57	Moores Creek transducer
6-19-86 (170)	50	19.5	-.05	-.09	-.14	-.30	-.16	
7-3-87 (184)	30	31.0	-.06	+.06	0	-.17	-.17	
7-2-86 (183)	25	35.5	-.09	-.05	-.14	-.25	-.11	
7-23-86 (204)	25	35.5	-.07	-.05	-.12	-.12	0	Gage insulated
7-7-87 (188)	18	51.5	-.09	+.06	-.03	-.10	-.07	
7-15-87 (196)	18	51.5	-.05	+.08	+.03	+.02	-.01	Galvanized shield
7-26-87 (207)	18	51.5	-.06	+.09	+.03	-.01	-.04	Brown shield
8-3-86 (215)	0	35.0	-.07	-.05	-.12	-.08	+.04	Insulated
8-16-86 (228)	0	35.0	-.08	-.04	-.12	-.13	-.01	
8-20-86 (232)	0	35.0	-.10	-.05	-.15	-.15	0	Recorder on top
8-31-86 (243)	0	9.0	-.03	-.10	-.13	-.16	-.03	
8-4-87 (216)	100 <sup>6/</sup>	12.0	-.03	+.08	+.05	-.20	-.25	
8-11-87 (223)	40 <sup>7/</sup>	13.0	-.04	+.08	+.04	-.13	-.17	

1/ Change in pressure head caused by expansion of the precipitation gage system.

2/ Change in pressure head caused by temperature effects on the transducer as determined from laboratory tests.

3/ Sum of 1/ and 2/.

4/ Change in pressure recorded by DAS or DCP.

5/ Difference of 4/ minus 3/.

6/ 100% ethylene glycol.

7/ 40% methyl alcohol - 60% water.

Table 3. Comparison of observed and calculated diurnal pressure changes for a simulated remote precipitation gage system in Boise, Idaho. Line valve between gage and shelter closed except as noted.

Date & (Julian Day)	Percent Methyl-Glycol in Mixture	Fluid Depth (inches)	Pressure Change (inches of water)					Remarks
			Computed	Transducer Correction	Total	Observed	Difference	
			<u>1/</u>	<u>2/</u>	<u>3/</u>	<u>4/</u>	<u>5/</u>	
6-25-87 (176)	95	11	-.07	+.10	+.03	+.25	+.22	
10-15-86 (288)	85	11	-.55	-.11	-.66	+3.18	+3.84	
6-26-86 (177)	50	20	-.16	-.09	-.25	-.05	+.20	
7-17-86 (198)	25	35	-.29	-.05	-.34	-.17	+.17	
7-28-86 (209)	25	35	-.25	-.05	-.30	-.09	+.21	Insulated
7-13-87 (194)	18	51.5	-.29	+.08	-.21	-.67	-.46	
8-9-86 (221)	0	35	-.26	-.06	-.32	-.19	+.13	Insulated
8-24-86 (236)	0	35	-.24	-.05	-.29	-.14	+.15	Recorder on top
9-3-86 (246)	0	9	-.12	-.11	-.23	-.15	+.08	
8-8-87 (220)	100 <sup>6/</sup>	12	-.08	+.10	+.02	+.10	+.08	100% ethylene glycol
6-13-86 (164)	100	9	-.13	-.12	-.25	+.31	+.56	Gage valve closed
6-27-87 (178)	95	10.5	-.10	+.09	-.01	+.21	+.22	Gage valve closed
10-8-86 (281)	85	11	-.83	-.10	-.93	+5.16	+6.09	Gage valve closed

<sup>1/</sup> Change in pressure head caused by expansion of the precipitation gage system.

<sup>2/</sup> Change in pressure head caused by temperature effects on the transducer as determined from laboratory tests.

<sup>3/</sup> Sum of <sup>1/</sup> and <sup>2/</sup>.

<sup>4/</sup> Change in pressure recorded by DAS or DCP.

<sup>5/</sup> Difference of <sup>4/</sup> minus <sup>3/</sup>.

<sup>6/</sup> 100% ethylene glycol.

followed the same procedure and theory presented in last year's report (See ARS-SCS Annual Progress Report No. 6, December 1986). The calculations were made for one day of a 3 to 10 day period during which time the fluid and system conditions were unchanged. The expected change in pressure transducer readings due to observed temperature changes was calculated as a function of the expansion characteristics of the precipitation gage system components plus the change in transducer readings with temperature as established by laboratory testing. In all cases, the calculations were made for the time from minimum temperature readings (early morning) to maximum temperature readings (late afternoon). The precipitation gage and most of the plumbing lines were generally expanding during this period which causes a reduction in pressure head, thus all of the computed changes have a negative sign.

The transducer corrections, on the other hand, depend on the transducer characteristics, and can be positive or negative. The transducer used for most of 1986 exhibited a negative response (decrease) to temperature increase, while the transducer used in 1987 had a positive (increase) response. A transducer which showed considerable diurnal fluctuation at the Moores Creek Summit, Idaho SNOTEL site, was installed at the Boise simulated SNOTEL site for the 10-29-86 period. As noted in Table 2, the transducer correction factor for this transducer, which is based on laboratory tests, was much larger than for either of the other transducers used. Thus, much of the fluctuation observed in the previous Moores Creek readings was due to temperature sensitivity of this transducer. This was further substantiated when later readings from Moores Creek using a different transducer showed much smaller fluctuations.

Examination of Table 2 reveals that except for two periods (10-29-86 and 7-15-87), the effect of temperature on the expansion of the system was greater than its effect on the transducer. Thus, the observed pressure changes based on transducer readings were generally negative, that is as temperature increased, pressure decreased (see observed pressure change). Calculated changes in pressure were less than observed changes for all but one day (8-3-86), where a very minor difference was determined.

The information in Table 2 is presented as a function of the amount of methyl alcohol-ethylene glycol in the mixture (from 100% to 0%). During the last two periods shown at the bottom of Table 2, the fluid consisted of 100 percent ethylene glycol or a mixture of methyl alcohol and water. These two cases were included to determine the response characteristics of the two compounds separately. As noted, they both produced essentially the same results. The arrangement of study periods as a function of percent methyl alcohol-ethylene glycol was selected, because it was noted that the difference between calculated and observed pressure change was larger for the higher percentages of this compound. For mixtures with methyl alcohol-ethylene glycol of 25 percent or less, differences between calculated and observed pressure changes are probably as small as could be expected considering measurement and calculation errors.

Since the fluid characteristics should have no effect on the pressure change (i.e., changes in density due to temperature changes are compensated by changes in volume; therefore, the weight of a column of fluid or the pressure would remain the same), it appears that the methyl alcohol-ethylene glycol is affecting the transducer in some way. Efforts to determine this influence have, however, not been successful. In any case, by spring when the temperature changes appear to cause the greatest diurnal fluctuations, the percent of methyl alcohol-ethylene glycol in the precipitation gage should be the smallest because it is diluted by winter precipitation. Therefore, if good pressure transducers are being used and temperature corrections are being applied, the adjusted readings should be reliable.

Table 3 contains results similar to those in Table 2, except the line valve or gage valve are closed (Fig. 1). Differences between calculated and observed pressure changes are greater under these conditions than for the open system. The larger differences may be partially due to calculation and measurement errors associated with the considerably smaller volumes and areas involved when the precipitation gage reservoir is shut off from the transducer side of the system. It is interesting that the calculated changes are greater than observed changes in all but one case, which is opposite of the results shown in Table 2 for the open system. Only the calculations for the periods with 100 percent water or ethylene glycol were within acceptable limits.

Two periods are of particular interest because of the extremely large differences between observed and calculated pressure change (10-15-86 and 10-8-86). The calculated pressure changes for these two periods indicated a large decrease due to system expansion and transducer effects; however, observed readings showed a very large increase in pressure. Since these results were representative of 3 or more days, it does not appear to be caused by random noise or error in readings. Careful study of the various temperatures and system conditions did not suggest a cause for these uncharacteristic values. Since a system with either valve closed is not representative of field conditions, these results, while intended to aid in isolating the problem, are probably of little value.

Table 4 contains a comparison of computed and observed changes in manometer readings due to expansion of the system and the various fluids. Since the fluids have considerably greater coefficients of thermal expansion than the materials in the system, the manometer readings increase with increasing temperature. Computed changes were greater than observed about 70 percent of the time. All of the differences except one (7-26-87) were 0.27 inches or less, and most were less than 0.19 inches, which is estimated to be within maximum calculation and measurement error limits. Examination of temperature patterns and magnitudes did not reveal any obvious reason for the dramatic change in manometer readings noted during the 7-26-87 period. Since expansion characteristics of the various fluids are considered in the calculations, as long as the various expansion coefficients are known, there should not be any pattern or tendency for differences to be greater or less for any given fluid. This, in fact, appeared to be the case and the magnitude of the differences for both manometers seemed to

Table 4. Comparison of computed and observed manometer readings for the shelter and gage manometers (Inches). All valves are open except as noted.

Date & (Julian Day)	Percent Methyl-Glycol	Change in Manometer Reading During the Day						Remarks
		Shelter			Gage			
		Computed	Observed	Difference	Computed	Observed	Difference	
8-18-87 (230)	100	--	--	--	+.28	+.13	-.15	
8-24-87 (236)	100	+.18	+.06	-.12	+.18	+.16	-.02	White
9-2-87 (245)	100	+.22	+.03	-.19	+.22	+.09	-.13	Brown
6-13-87 (164)	95	+.33	+.19	-.14	+.33	+.31	-.02	
7-3-87 (184)	30	+.74	+.72	-.02	+.28	+.44	+.16	
7-2-86 (183)	25	+.38	+.34	-.04	--	--	--	
7-23-86 (204)	25	+.30	+.50	+.20	--	--	--	Insulated
7-7-87 (188)	18	+.92	+.94	+.02	+.31	+.53	+.22	
7-15-87 (196)	18	+.67	+.41	-.26	--	--	--	Galvanized shield
7-26-87 (207)	18	+.57	+1.44	+.87	--	--	--	Brown shield
8-16-86 (228)	0	+.13	+.16	+.03	--	--	--	
8-20-86 (232)	0	+.16	+.28	+.12	--	--	--	Recorder on top
8-11-87 (223)	40% methanol 60% water	+.21	+.13	-.08	+.21	+.19	-.02	
8-4-86 (216)	100% ethylene glycol	+.26	+.19	-.07	+.26	+.25	-.01	
6-25-87 (176)	95	+.64	+.56	-.08	+.33	+.25	-.08	Valve closed
6-26-86 (177)	50	+.44	+.44	0	--	--	--	Valve closed
7-13-87 (194)	18	+.81	+.75	-.06	+.38	+.63	+.25	Valve closed
8-8-87 (220)	100% ethylene glycol	+.40	+.31	-.09	+.24	+.19	-.05	Valve closed
6-13-86 (164)	100	+.64	+.69	+.05	--	--	--	Gage valve closed
6-27-87 (178)	95	+1.02	+.75	-.27	+.31	+.19	-.12	Gage valve closed

be random which suggested noise in the data. If this is the case, these calculations would tend to act as a check on the theory and procedures used in all of the calculations, and would therefore strengthen the conclusions obtained using Table 2 results.

The magnitude of the difference between observed and calculated manometer change could be affected by timing of the manometer observations. Although calculated values were based on the period from minimum temperature to maximum temperature, manometer readings were taken in the early morning and late afternoon. Temperature during the early morning did not change dramatically from its minimum value, but afternoon temperatures varied considerably with maximums occurring as early as 4:00 p.m. and as late as 9:00 p.m. Therefore, the time period used in the calculations did not necessarily coincide with the time period between manometer readings, and could be the cause of some of the differences noted.

A comparison of results shown in Tables 2, 3, and 4 indicates that periods with large differences between observed and calculated pressure did not coincide with periods of large differences between observed and calculated manometer changes.

#### Recommendations

The changes most likely to reduce diurnal fluctuations in precipitation gage readings based on tests conducted at the simulated SNOTEL site, in order of priority, are:

1. Exchange the pressure transducer with one of known thermal characteristics determined by laboratory tests.
2. Change the thermal regime of the precipitation gage using; a) shielding, b) insulation, or c) light colored insulating paints.
3. Change the characteristics of the anti-freeze solution.
4. Change the design of the precipitation gage.

Field tests of the first two recommendations should be conducted before considering items 3 and 4.

## B. Transducer Response in Laboratory and Field Tests

The analysis presented in the previous section indicated that temperature effects on the system, the transducer, and the fluid could account for the magnitude of diurnal fluctuations observed at the simulated SNOTEL site (see Table 2). If the same relationships were valid for field sites, a correction could be applied which should eliminate the diurnal fluctuations. To check this hypothesis, a study was initiated that consisted of an analysis of SNOTEL data and laboratory testing of the pressure transducers used.

The first part of the study involved collecting data from all 517 SNOTEL sites during a precipitation-free period in June of 1987, at a frequency of four or more readings per day. These data were analyzed to determine the magnitude of the observed pressure change and its relationship to the observed temperature at the site. Those stations which exhibited a diurnal pressure fluctuation greater than that permitted by the pressure transducer specifications were then identified. The next step was to obtain new transducers from the factory and to establish a relationship between temperature and transducer output for a specified pressure and temperature range. These new transducers were then installed at the field sites identified above where possible.

The next phase of the study involved laboratory testing of the old transducers removed from the field sites to establish their temperature-pressure relationships. Also, data from the field sites with the new transducers installed were obtained during a precipitation-free period in October 1987. The data were again analyzed to determine the magnitude of the diurnal pressure fluctuations as a function of site temperature.

In all, 20 new pressure transducers were tested in the laboratory. However, because the transducers were received late in the year, after most of the field sites had been visited and recharged in preparation for winter snows, only seven new transducers were installed at known sites and only eight of the old transducers were submitted to the laboratory for testing.

Laboratory tests and field data were available for both old and new transducers from only four sites in Idaho. The transducer identification numbers and their locations during June and October 1987 are shown in Table 5. The laboratory test results showing the transducer outputs for a range of temperatures and pressures are presented in Tables 6-13.

Analysis of the data from the SNOTEL sites is presented in Section C. Using the results presented and the offsets obtained from SCS, the depth of the fluid in the gage, the approximate concentration of methyl alcohol-ethylene glycol in the mixture, and the change in pressure with temperature were determined. Using the laboratory test results, the relationship between pressure and temperature for each transducer was developed. Since this relationship was found to vary with pressure head, it was necessary to develop the relation for a range of depths or heads, and interpolate for actual depths. The approximate depth

Table 5. Transducers located at selected field SNOTEL sites in Idaho during June and October 1987, and the regression parameters developed from SNOTEL and laboratory temperature and pressure data.

Month	Data	Stickney Mill			Vienna Mine			Banner Summit			Moore's Creek		
		Transducer no.	Intercept	Slope	Transducer no.	Intercept	Slope	Transducer no.	Intercept	Slope	Transducer no.	Intercept	Slope
JUN	SNOTEL	600	19.95	-0.036	139	59.39	0.042	290	13.00	0.043	338	26.70	0.032
	Lab	600	20.00	-0.022	139	59.37	0.032	290	13.10	0.012	338	26.70	0.007
OCT	SNOTEL	1400	25.37	0.014	1394	29.28	0.002	1406	16.52	0.016	1401	5.12	0.017
	Lab	1400	25.38	0.007	1394	29.28	0.010	1406	16.35	0.011	1401	5.20	-0.003

Table 6. Test of pressure transducer output as a function of temperature for Robinson-Halpern transducer, serial no. 139.

TEMPERATURE TEST FOR ROBINSON-HALPERN TRANSDUCER

MODEL: 159AW215DV35BS

SERIAL NO.: 139

RANGE: 0 - 150 INCHES H<sub>2</sub>O

SUPPLY: 7.50 VDC

OUTPUT: 0-5 VDC

CONDITION: USED - OUTPUT SLOW TO STABILIZE AFTER PRESSURE CHANGE

ADJUSTMENTS: NONE

=====										
INPUT										
PRESSURE										
(INCHES H <sub>2</sub> O)	0"	20"	40"	60"	80"	100"	110"	120"	130"	150"
=====										
TEST										
TEMPERATURE										
=====										
TRANSDUCER OUTPUT										
(INCHES H <sub>2</sub> O)										
=====										
50 C	2.22	21.60	41.88	62.43	82.29	101.79	111.54	122.34	132.42	152.19
40 C	1.53	21.42	41.79	62.16	81.84	101.88	112.14	122.22	131.88	151.65
30 C	3.57	22.08	41.88	62.01	82.08	101.94	111.69	121.95	131.85	151.35
20 C	1.29	21.21	41.40	61.32	81.54	101.43	111.51	121.71	131.76	150.87
10 C	.90	21.00	41.01	61.32	81.15	101.40	111.18	121.05	131.10	150.78
0 C	1.44	20.64	40.83	61.05	80.79	100.65	110.55	120.42	130.41	150.00
-5 C	.93	20.58	40.50	60.63	80.61	100.32	110.07	119.79	130.11	149.22
-10 C	.90	20.34	40.47	60.54	80.61	100.50	110.16	119.99	129.78	149.44
-15 C	.45	20.28	40.23	60.33	80.25	100.24	110.10	119.74	129.57	149.16
=====										

TEST PROCEDURE:

1. THE TRANSDUCER WAS PLACED IN A FREAS MODEL 815 INCUBATOR AND THE TEMPERATURE WAS ALLOWED TO STABILIZE FOR 30 MINUTES BEFORE READING TRANSDUCER OUTPUT.
2. DRUCK MODEL DP1600 DIGITAL PRESSURE INDICATOR WAS USED AS THE PRESSURE REFERENCE AND WAS OPERATED AT ROOM TEMPERATURE UTILIZING AIR AS THE PRESSURE MEDIUM.
3. FLUKE MODEL 8050A 4-1/2 DIGIT MULTIMETER WAS USED FOR TRANSDUCER OUTPUT VOLTAGE MEASUREMENT.
4. THE 7.50 VOLT SUPPLY VOLTAGE WAS APPLIED TO THE TRANSDUCER DURING MEASUREMENT ONLY AND WAS DISCONNECTED DURING TEMPERATURE STABILIZATION.
5. THE 7.50 VOLT SUPPLY WAS CHECKED BEFORE EVERY MEASUREMENT AND WAS MAINTAINED AT 7.50 VOLT +/- .005 VOLT.
6. THE PRESSURE WAS INCREASED TO THE TEST VALUES WITHOUT OVERSHOOT TO MINIMIZE THE EFFECTS OF HYSTERESIS.

Table 7. Test of pressure transducer output as a function of temperature for Robinson-Halpern transducer, serial no. 290.

TEMPERATURE TEST FOR ROBINSON-HALPERN TRANSDUCER

MODEL: 159AW210DV35BS  
 SERIAL NO.: 290  
 RANGE: 0 - 100 INCHES H<sub>2</sub>O  
 SUPPLY: 7.50 VDC  
 OUTPUT: 0-5 VDC  
 CONDITION: USED  
 ADJUSTMENTS: NONE

=====										
INPUT										
PRESSURE										
(INCHES H <sub>2</sub> O)	0"	10"	20"	30"	40"	50"	60"	70"	80"	100"
=====										
TEST										
TEMPERATURE										
=====										
TRANSDUCER OUTPUT										
(INCHES H <sub>2</sub> O)										
=====										
50 C	.56	10.68	20.78	30.76	40.84	50.86	60.84	70.86	80.88	100.86
40 C	.54	10.60	20.70	30.72	40.74	50.72	60.76	70.74	80.72	100.72
30 C	.34	10.46	20.54	30.58	40.64	50.62	60.62	70.64	80.56	100.56
20 C	.20	10.32	20.42	30.46	40.46	50.46	60.44	70.44	80.42	100.38
10 C	.08	10.20	20.24	30.28	40.32	50.30	60.30	70.28	80.26	100.22
0 C	-.04	10.02	20.14	30.16	40.16	50.16	60.18	70.18	80.16	100.08
-5 C	-.08	10.04	20.08	30.08	40.12	50.12	60.10	70.08	80.10	100.04
-10 C	-.12	9.98	20.02	30.06	40.10	50.12	60.08	70.10	80.04	100.02
-15 C	-.18	9.92	19.98	30.00	40.02	50.04	60.04	70.00	80.00	99.96
=====										

TEST PROCEDURE:

1. THE TRANSDUCER WAS PLACED IN A FREAS MODEL 815 INCUBATOR AND THE TEMPERATURE WAS ALLOWED TO STABILIZE FOR 30 MINUTES BEFORE READING TRANSDUCER OUTPUT.
2. DRUCK MODEL DP1600 DIGITAL PRESSURE INDICATOR WAS USED AS THE PRESSURE REFERENCE AND WAS OPERATED AT ROOM TEMPERATURE UTILIZING AIR AS THE PRESSURE MEDIUM.
3. FLUKE MODEL 8050A 4-1/2 DIGIT MULTIMETER WAS USED FOR TRANSDUCER OUTPUT VOLTAGE MEASUREMENT.
4. THE 7.50 VOLT SUPPLY VOLTAGE WAS APPLIED TO THE TRANSDUCER DURING MEASUREMENT ONLY AND WAS DISCONNECTED DURING TEMPERATURE STABILIZATION.
5. THE 7.50 VOLT SUPPLY WAS CHECKED BEFORE EVERY MEASUREMENT AND WAS MAINTAINED AT 7.50 VOLT +/- .005 VOLT.
6. THE PRESSURE WAS INCREASED TO THE TEST VALUES WITHOUT OVERSHOOT TO MINIMIZE THE EFFECTS OF HYSTERISIS.

Table 8. Test of pressure transducer output as a function of temperature for Robinson-Halpern transducer, serial no. 338.

TEMPERATURE TEST FOR ROBINSON-HALPERN TRANSDUCER

MODEL: 159AW150DV35BS  
 SERIAL NO.: 338  
 RANGE: 0 - 50 INCHES H<sub>2</sub>O  
 SUPPLY: 7.50 VDC  
 OUTPUT: 0-5 VDC  
 CONDITION: USED  
 ADJUSTMENTS: NONE

=====										
INPUT										
PRESSURE										
(INCHES H <sub>2</sub> O)	0"	10"	15"	20"	25"	30"	35"	40"	45"	50"
=====										
TEST										
TEMPERATURE										
=====										
TRANSDUCER OUTPUT										
(INCHES H <sub>2</sub> O)										
=====										
50 C	.00	10.09	15.18	20.28	25.44	30.56	35.68	40.76	45.79	50.81
40 C	.14	10.19	15.29	20.39	25.51	30.59	35.68	40.75	45.76	50.77
30 C	.13	10.22	15.26	20.37	25.42	30.54	35.60	40.65	45.70	50.64
20 C	.12	10.16	15.23	20.30	25.35	30.43	35.48	40.50	45.52	50.47
10 C	.12	10.08	15.11	20.18	25.22	30.30	35.32	40.37	45.31	50.23
0 C	.11	10.08	15.10	20.15	25.17	30.21	35.25	40.22	45.20	50.09
-5 C	.10	10.04	15.10	20.13	25.17	30.20	35.21	40.20	45.10	50.00
-10 C	.09	10.03	15.05	20.08	25.10	30.13	35.16	40.16	45.04	49.94
-15 C	.08	10.02	15.03	20.04	25.10	30.13	35.12	40.09	45.00	49.87
=====										

TEST PROCEDURE:

1. THE TRANSDUCER WAS PLACED IN A FREAS MODEL 815 INCUBATOR AND THE TEMPERATURE WAS ALLOWED TO STABILIZE FOR 30 MINUTES BEFORE READING TRANSDUCER OUTPUT.
2. DRUCK MODEL DP1600 DIGITAL PRESSURE INDICATOR WAS USED AS THE PRESSURE REFERENCE AND WAS OPERATED AT ROOM TEMPERATURE UTILIZING AIR AS THE PRESSURE MEDIUM.
3. FLUKE MODEL 8050A 4-1/2 DIGIT MULTIMETER WAS USED FOR TRANSDUCER OUTPUT VOLTAGE MEASUREMENT.
4. THE 7.50 VOLT SUPPLY VOLTAGE WAS APPLIED TO THE TRANSDUCER DURING MEASUREMENT ONLY AND WAS DISCONNECTED DURING TEMPERATURE STABILIZATION.
5. THE 7.50 VOLT SUPPLY WAS CHECKED BEFORE EVERY MEASUREMENT AND WAS MAINTAINED AT 7.50 VOLT +/- .005 VOLT.
6. THE PRESSURE WAS INCREASED TO THE TEST VALUES WITHOUT OVERSHOOT TO MINIMIZE THE EFFECTS OF HYSTERESIS.

Table 9. Test of pressure transducer output as a function of temperature for Robinson-Halpern transducer, serial no. 600.

TEMPERATURE TEST FOR ROBINSON-HALPERN TRANSDUCER

MODEL: 159AW210DV35BS  
 SERIAL NO.: 600  
 RANGE: 0 - 100 INCHES H<sub>2</sub>O  
 SUPPLY: 7.50 VDC  
 OUTPUT: 0-5 VDC  
 CONDITION: USED  
 ADJUSTMENTS: NONE

=====										
INPUT										
PRESSURE										
(INCHES H <sub>2</sub> O)	0"	10"	20"	30"	40"	50"	60"	70"	80"	100"
=====										
TEST										
TEMPERATURE										
=====										
TRANSDUCER OUTPUT										
(INCHES H <sub>2</sub> O)										
=====										
50 C	-1.24	9.08	19.32	29.54	39.76	49.94	60.12	70.34	80.50	100.76
40 C	-.98	9.34	19.58	29.84	40.04	50.22	60.42	70.60	80.76	101.00
30 C	-.74	9.60	19.86	30.10	40.30	50.52	60.70	70.82	80.98	101.30
20 C	-.48	9.88	20.16	30.36	40.58	50.76	61.00	71.10	81.24	101.48
10 C	-.22	10.10	20.38	30.62	40.84	51.06	61.20	71.38	81.52	101.76
0 C	-.04	10.30	20.58	30.84	41.06	51.30	61.42	71.60	81.72	101.92
-5 C	.00	10.32	20.64	30.90	41.10	51.32	61.52	71.64	81.80	102.01
-10 C	.04	10.44	20.68	30.96	41.18	51.38	61.56	71.74	81.90	102.10
-15 C	.12	10.46	20.76	31.00	41.22	51.40	61.58	71.76	81.90	102.10
=====										

TEST PROCEDURE:

1. THE TRANSDUCER WAS PLACED IN A FREAS MODEL 815 INCUBATOR AND THE TEMPERATURE WAS ALLOWED TO STABILIZE FOR 30 MINUTES BEFORE READING TRANSDUCER OUTPUT.
2. DRUCK MODEL DP1600 DIGITAL PRESSURE INDICATOR WAS USED AS THE PRESSURE REFERENCE AND WAS OPERATED AT ROOM TEMPERATURE UTILIZING AIR AS THE PRESSURE MEDIUM.
3. FLUKE MODEL 8050A 4-1/2 DIGIT MULTIMETER WAS USED FOR TRANSDUCER OUTPUT VOLTAGE MEASUREMENT.
4. THE 7.50 VOLT SUPPLY VOLTAGE WAS APPLIED TO THE TRANSDUCER DURING MEASUREMENT ONLY AND WAS DISCONNECTED DURING TEMPERATURE STABILIZATION.
5. THE 7.50 VOLT SUPPLY WAS CHECKED BEFORE EVERY MEASUREMENT AND WAS MAINTAINED AT 7.50 VOLT +/- .005 VOLT.
6. THE PRESSURE WAS INCREASED TO THE TEST VALUES WITHOUT OVERSHOOT TO MINIMIZE THE EFFECTS OF HYSTERESIS.

Table 10. Test of pressure transducer output as a function of temperature for Robinson-Halpern transducer, serial no. 1394.

TEMPERATURE TEST FOR ROBINSON-HALPERN TRANSDUCER

MODEL: 159AW210D35U  
 SERIAL NO.: 1394  
 RANGE: 0 - 100 INCHES H<sub>2</sub>O  
 SUPPLY: 7.50 VDC  
 OUTPUT: 0-5 VDC  
 CONDITION: NEW  
 ADJUSTMENTS: NONE

=====										
INPUT										
PRESSURE										
(INCHES H <sub>2</sub> O)	0"	10"	20"	30"	40"	50"	60"	70"	80"	100"
=====										
TEST										
TEMPERATURE										
=====										
TRANSDUCER OUTPUT										
(INCHES H <sub>2</sub> O)										
=====										
50 C	.10	10.30	20.56	30.70	40.88	51.04	61.18	71.36	81.40	100.14
40 C	.06	10.30	20.48	30.66	40.84	51.02	61.18	71.32	81.34	100.06
30 C	.06	10.32	20.50	30.70	40.88	51.06	61.20	71.32	81.32	100.02
20 C	.02	10.24	20.40	30.56	40.74	50.90	61.04	71.14	81.20	99.88
10 C	-.08	10.08	20.24	30.42	40.60	50.74	60.88	70.98	81.02	99.66
0 C	-.22	9.96	20.12	30.30	40.48	50.60	60.72	70.86	80.88	99.50
-5 C	-.28	9.86	20.00	30.12	40.20	50.32	60.40	70.46	80.46	99.02
-10 C	-.32	9.88	20.04	30.20	40.34	50.50	60.64	70.78	80.76	99.42
-15 C	-.38	9.80	19.98	30.16	40.28	50.42	60.56	70.66	80.68	99.32
=====										

TEST PROCEDURE:

1. THE TRANSDUCER WAS PLACED IN A FREAS MODEL 815 INCUBATOR AND THE TEMPERATURE WAS ALLOWED TO STABILIZE FOR 30 MINUTES BEFORE READING TRANSDUCER OUTPUT.
2. DRUCK MODEL DP1600 DIGITAL PRESSURE INDICATOR WAS USED AS THE PRESSURE REFERENCE AND WAS OPERATED AT ROOM TEMPERATURE UTILIZING AIR AS THE PRESSURE MEDIUM.
3. FLUKE MODEL 8050A 4-1/2 DIGIT MULTIMETER WAS USED FOR TRANSDUCER OUTPUT VOLTAGE MEASUREMENT.
4. THE 7.50 VOLT SUPPLY VOLTAGE WAS APPLIED TO THE TRANSDUCER DURING MEASUREMENT ONLY AND WAS DISCONNECTED DURING TEMPERATURE STABILIZATION.
5. THE 7.50 VOLT SUPPLY WAS CHECKED BEFORE EVERY MEASUREMENT AND WAS MAINTAINED AT 7.50 VOLT +/- .005 VOLT.
6. THE PRESSURE WAS INCREASED TO THE TEST VALUES WITHOUT OVERSHOOT TO MINIMIZE THE EFFECTS OF HYSTERISIS.

Table 11. Test of pressure transducer output as a function of temperature for Robinson-Halpern transducer, serial no. 1400.

TEMPERATURE TEST FOR ROBINSON-HALPERN TRANSDUCER

MODEL: 159AW210D35U  
 SERIAL NO.: 1400  
 RANGE: 0 - 100 INCHES H<sub>2</sub>O  
 SUPPLY: 7.50 VDC  
 OUTPUT: 0-5 VDC  
 CONDITION: NEW  
 ADJUSTMENTS: NONE

=====										
INPUT										
PRESSURE										
(INCHES H <sub>2</sub> O)	0"	10"	20"	30"	40"	50"	60"	70"	80"	100"
=====										
TEST										
TEMPERATURE										
=====										
TRANSDUCER OUTPUT										
(INCHES H <sub>2</sub> O)										
=====										
50 C	.24	10.40	20.58	30.72	40.82	50.88	60.96	70.96	80.98	100.38
40 C	.26	10.46	20.62	30.74	40.80	50.92	60.96	70.96	80.98	100.38
30 C	.26	10.50	20.60	30.74	40.78	50.88	60.90	70.92	80.92	100.22
20 C	.20	10.36	20.50	30.60	40.66	50.72	60.78	70.74	80.72	100.06
10 C	.14	10.28	20.40	30.48	40.56	50.62	60.68	70.64	80.64	99.96
0 C	.10	10.26	20.36	30.46	40.52	50.58	60.56	70.56	80.54	99.84
-5 C	.08	10.22	20.24	30.30	40.30	50.30	60.26	70.22	80.12	99.36
-10 C	.00	10.16	20.24	30.36	40.38	50.44	60.48	70.48	80.40	99.70
-15 C	-.02	10.14	20.22	30.32	40.38	50.38	60.38	70.40	80.34	99.64
=====										

TEST PROCEDURE:

1. THE TRANSDUCER WAS PLACED IN A FREAS MODEL 815 INCUBATOR AND THE TEMPERATURE WAS ALLOWED TO STABILIZE FOR 30 MINUTES BEFORE READING TRANSDUCER OUTPUT.
2. DRUCK MODEL DP1600 DIGITAL PRESSURE INDICATOR WAS USED AS THE PRESSURE REFERENCE AND WAS OPERATED AT ROOM TEMPERATURE UTILIZING AIR AS THE PRESSURE MEDIUM.
3. FLUKE MODEL 8050A 4-1/2 DIGIT MULTIMETER WAS USED FOR TRANSDUCER OUTPUT VOLTAGE MEASUREMENT.
4. THE 7.50 VOLT SUPPLY VOLTAGE WAS APPLIED TO THE TRANSDUCER DURING MEASUREMENT ONLY AND WAS DISCONNECTED DURING TEMPERATURE STABILIZATION.
5. THE 7.50 VOLT SUPPLY WAS CHECKED BEFORE EVERY MEASUREMENT AND WAS MAINTAINED AT 7.50 VOLT +/- .005 VOLT.
6. THE PRESSURE WAS INCREASED TO THE TEST VALUES WITHOUT OVERSHOOT TO MINIMIZE THE EFFECTS OF HYSTERISIS.

Table 12. Test of pressure transducer output as a function of temperature for Robinson-Halpern transducer, serial no. 1401.

TEMPERATURE TEST FOR ROBINSON-HALPERN TRANSDUCER										
MODEL: 159AW210D35U										
SERIAL NO.: 1401										
RANGE: 0 - 100 INCHES H <sub>2</sub> O										
SUPPLY: 7.50 VDC										
OUTPUT: 0-5 VDC										
CONDITION: NEW										
ADJUSTMENTS: NONE										
=====										
INPUT										
PRESSURE										
(INCHES H <sub>2</sub> O)	0"	10"	20"	30"	40"	50"	60"	70"	80"	100"
=====										
TEST										
TEMPERATURE										
=====										
TRANSDUCER OUTPUT										
(INCHES H <sub>2</sub> O)										
=====										
50 C	.16	10.16	20.14	30.14	40.14	50.14	60.14	70.14	80.16	100.12
40 C	.12	10.16	20.12	30.12	40.12	50.16	60.12	70.12	80.12	100.10
30 C	.22	10.16	20.16	30.14	40.14	50.12	60.12	70.08	80.12	100.06
20 C	.24	10.24	20.18	30.18	40.14	50.16	60.16	70.12	80.10	100.02
10 C	.30	10.24	20.18	30.18	40.14	50.10	60.12	70.10	80.04	99.96
0 C	.28	10.26	20.22	30.14	40.14	50.12	60.08	70.04	80.02	99.92
-5 C	.32	10.30	20.24	30.20	40.12	50.12	60.14	70.08	80.04	99.90
-10 C	.32	10.28	20.26	30.22	40.16	50.16	60.12	70.08	80.08	99.96
-15 C	.38	10.34	20.28	30.26	40.24	50.16	60.16	70.12	80.10	99.96
=====										

TEST PROCEDURE:

1. THE TRANSDUCER WAS PLACED IN A FREAS MODEL 815 INCUBATOR AND THE TEMPERATURE WAS ALLOWED TO STABILIZE FOR 30 MINUTES BEFORE READING TRANSDUCER OUTPUT.
2. DRUCK MODEL DP1600 DIGITAL PRESSURE INDICATOR WAS USED AS THE PRESSURE REFERENCE AND WAS OPERATED AT ROOM TEMPERATURE UTILIZING AIR AS THE PRESSURE MEDIUM.
3. FLUKE MODEL 8050A 4-1/2 DIGIT MULTIMETER WAS USED FOR TRANSDUCER OUTPUT VOLTAGE MEASUREMENT.
4. THE 7.50 VOLT SUPPLY VOLTAGE WAS APPLIED TO THE TRANSDUCER DURING MEASUREMENT ONLY AND WAS DISCONNECTED DURING TEMPERATURE STABILIZATION.
5. THE 7.50 VOLT SUPPLY WAS CHECKED BEFORE EVERY MEASUREMENT AND WAS MAINTAINED AT 7.50 VOLT +/- .005 VOLT.
6. THE PRESSURE WAS INCREASED TO THE TEST VALUES WITHOUT OVERSHOOT TO MINIMIZE THE EFFECTS OF HYSTERISIS.

Table 13. Test of pressure transducer output as a function of temperature for Robinson-Halpern transducer, serial no. 1406.

TEMPERATURE TEST FOR ROBINSON-HALPERN TRANSDUCER

MODEL: 159AW210D35U  
 SERIAL NO.: 1406  
 RANGE: 0 - 100 INCHES H<sub>2</sub>O  
 SUPPLY: 7.50 VDC  
 OUTPUT: 0-5 VDC  
 CONDITION: NEW  
 ADJUSTMENTS: NONE

=====										
INPUT										
PRESSURE										
(INCHES H <sub>2</sub> O)	0"	10"	20"	30"	40"	50"	60"	70"	80"	100"
=====										
TEST										
TEMPERATURE										
=====										
TRANSDUCER OUTPUT										
(INCHES H <sub>2</sub> O)										
=====										
50 C	.52	10.76	20.96	31.16	41.26	51.38	61.50	71.52	81.56	100.86
40 C	.44	10.74	20.92	31.10	41.22	51.34	61.40	71.42	81.44	100.72
30 C	.30	10.62	20.82	30.98	41.16	51.24	61.32	71.34	81.38	100.66
20 C	.18	10.46	20.64	30.84	40.98	51.06	61.14	71.14	81.14	100.44
10 C	.02	10.28	20.48	30.68	40.80	50.90	60.96	71.00	81.00	100.28
0 C	-.08	10.14	20.36	30.54	40.72	50.78	60.86	70.90	80.88	100.18
-5 C	-.16	10.18	20.40	30.62	40.74	50.84	60.94	71.00	81.00	100.40
-10 C	-.14	10.12	20.34	30.58	40.72	50.82	60.94	70.94	80.98	100.32
-15 C	-.20	10.08	20.32	30.56	40.66	50.78	60.88	70.96	80.96	100.30
=====										

TEST PROCEDURE:

1. THE TRANSDUCER WAS PLACED IN A FREAS MODEL 815 INCUBATOR AND THE TEMPERATURE WAS ALLOWED TO STABILIZE FOR 30 MINUTES BEFORE READING TRANSDUCER OUTPUT.
2. DRUCK MODEL DP1600 DIGITAL PRESSURE INDICATOR WAS USED AS THE PRESSURE REFERENCE AND WAS OPERATED AT ROOM TEMPERATURE UTILIZING AIR AS THE PRESSURE MEDIUM.
3. FLUKE MODEL 8050A 4-1/2 DIGIT MULTIMETER WAS USED FOR TRANSDUCER OUTPUT VOLTAGE MEASUREMENT.
4. THE 7.50 VOLT SUPPLY VOLTAGE WAS APPLIED TO THE TRANSDUCER DURING MEASUREMENT ONLY AND WAS DISCONNECTED DURING TEMPERATURE STABILIZATION.
5. THE 7.50 VOLT SUPPLY WAS CHECKED BEFORE EVERY MEASUREMENT AND WAS MAINTAINED AT 7.50 VOLT +/- .005 VOLT.
6. THE PRESSURE WAS INCREASED TO THE TEST VALUES WITHOUT OVERSHOOT TO MINIMIZE THE EFFECTS OF HYSTERISIS.

(intercept at a temperature of 0 °C) and the change of pressure as a function of temperature (slope of regression line) are presented in Table 5 for the four sites and eight transducers studied. Results for the laboratory tests were obtained by interpolating between pressure settings used, according to the depth of fluid in the gage at the field sites. While these comparisons are not precise, they are sufficiently accurate to indicate the magnitude of errors that might be encountered in correcting field data using these methods. Of greater concern is the effect of the different temperatures involved. The field results are based on air temperature obtained from sensors located outside the instrument shelters, while laboratory results are based on actual transducer temperatures. As seen in Figures 2-16, air temperature and the temperature of the transducer in the instrument shelter are quite different at certain times. Thus the transducers at the field sites may be subjected to considerably greater temperature changes than those indicated by the air temperature readings.

The amount of pressure change expected for a 30 °C change in air temperature at the SNOTEL sites and a 40 °C change in transducer temperature in the laboratory are shown in Table 14 for each of the four Idaho SNOTEL sites. Changes due to expansion of the system and fluid characteristics are also included.

The results in Table 14 indicate that corrections to SNOTEL data, based on relationships developed from laboratory tests of the transducers and the simulated site for the system and fluid would improve accuracy in almost all cases. However, errors for both test periods at Moores Creek and for the June test period at Banner Summit would still be more than desirable. The Moores Creek results seem to indicate a consistent difference that could be caused by local conditions or system problems. At Banner Summit it appears that transducer #290 responded differently in the field than in the laboratory. Part of this difference could also be due to a different relationship between air temperature and transducer temperature than that assumed in the calculations.

The laboratory procedure for establishing a relationship between pressure and temperature changes of a transducer uses air as the fluid. A modification of this procedure can be made to use water, methyl alcohol-ethylene glycol, or other fluids. When this is done, the transducer is filled with the liquid desired and transducer and fluids are placed in a temperature controlled chamber. Air pressure is still used to provide a range of pressures, but it is applied to the column of fluid in the transducer. As a check on the use of air as the fluid, tests were also conducted using water and methyl alcohol-ethylene glycol in the same transducer (#1390) and subjected to the same temperature and pressure changes. The transducer outputs as a function of pressure and temperature are presented in Table 15. As noted, the outputs are not the same for all three fluids. However, differences are less than 3 percent in all cases, and as long as the same fluid was used in all tests, results should be within allowable limits.

Plots of temperature versus transducer output for a 60 inch pressure head are presented in Figure 22. Similar plots for the other pressure heads tested showed the same trends, indicating a consistency between

Table 14. Comparison of observed diurnal pressure fluctuations from SNOTEL sites in Idaho with estimated fluctuations based on temperature corrections to transducers, precipitation systems, and fluid characteristics (inches).

	Stickney Mill		Vienna Mine		Banner Summit		Moore's Creek	
	JUN	OCT	JUN	OCT	JUN	OCT	JUN	OCT
Estimated Change								
Transducer	-.88	-.28	1.28	.39	.48	.44	.28	-.12
System	-.05	-.05	-.07	-.06	-.03	-.04	-.06	-.02
Fluid	-.12	-.10	-.04	-.12	-.20	-.15	-.10	-.23
Total	-1.05	.13	1.17	.21	.25	.25	.12	-.37
Observed Change								
SNOTEL total	-1.08	.42	1.26	.06	1.29	.48	.96	.50
Difference between observed & estimated	-.03	.29	.09	-.15	1.04	.23	.84	.87

Table 15. Pressure transducer output as a function of pressure head and temperature for Robinson-Halpern transducer #1390 using three different fluid mediums.

Temperature °C	Pressure Head (Inches of water)											
	20				40				60			
	Air	G.M.	Water	Air	G.M.	Water	Air	G.M.	Water	Air	G.M.	Water
50°	20.49	20.13	19.89	40.89	40.08	39.99	61.17	59.94	59.85	81.33	79.89	79.56
40°	20.52	20.10	20.28	40.92	40.17	40.26	61.20	60.06	60.24	81.45	79.98	80.13
30°	20.46	20.16	20.13	40.86	40.20	40.23	61.20	60.21	60.21	81.42	80.04	80.13
20°	20.46	20.25	20.13	40.89	40.32	40.26	61.20	60.36	60.24	81.42	80.31	80.16
10°	20.49	20.25	20.16	40.89	40.41	40.26	61.20	60.48	60.24	81.39	80.46	80.19
0°	20.49	20.34		40.89	40.53		61.20	60.63		81.42	80.64	
-5°	20.43	20.37		40.86	40.56		61.14	60.63		81.36	80.70	
-10°	20.46	20.34		40.89	40.59		61.23	60.72		81.45	80.76	
-15°	20.46	20.37		40.89	40.56		61.20	60.72		81.39	80.82	

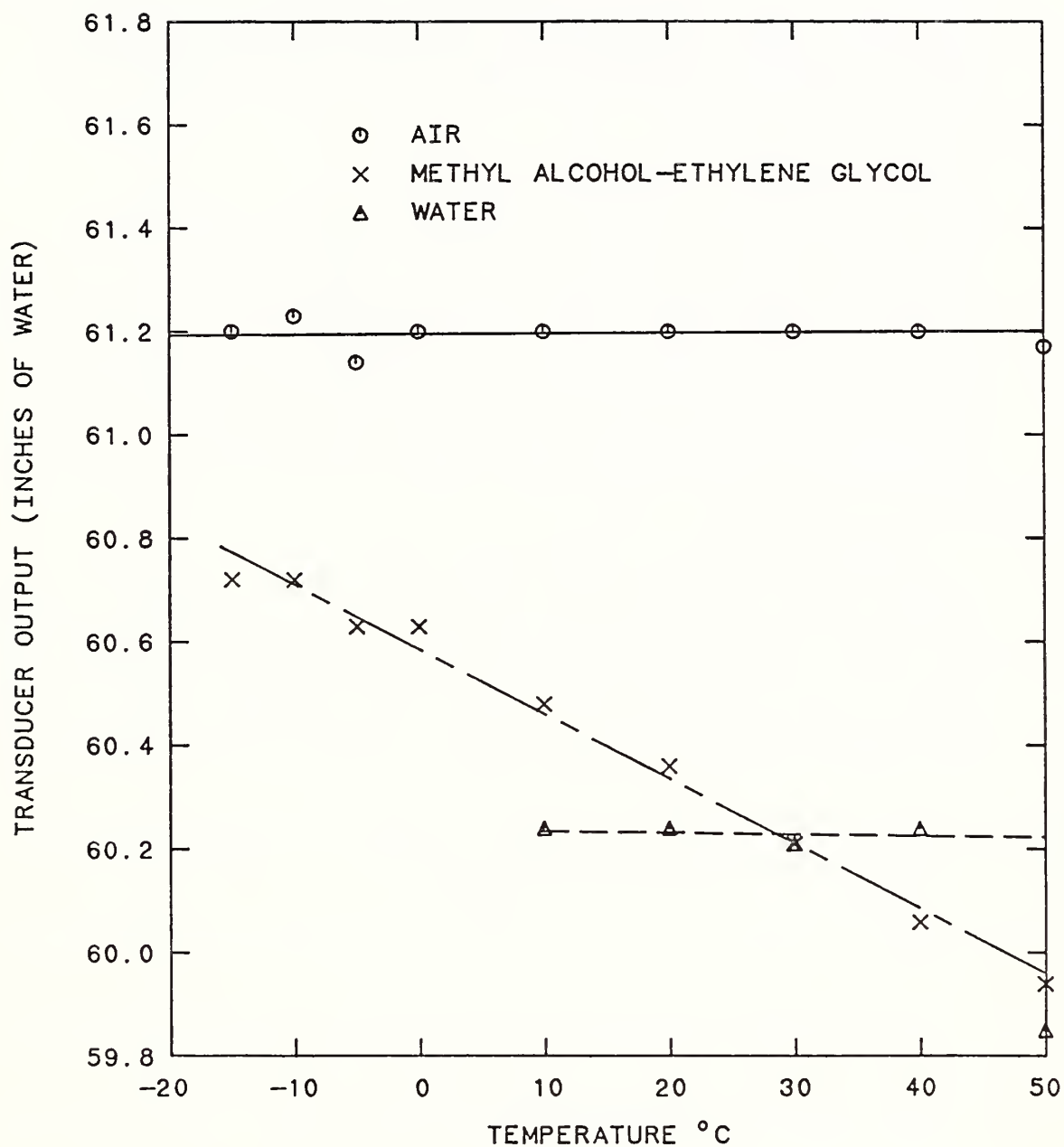


Figure 22. Laboratory tests of transducer output (inches of water) as a function of temperature (°C) for Robinson-Halpern transducer #1390 using air, water, and methyl alcohol-ethylene glycol as the fluids in the transducer under an imposed pressure of 60 inches of water.

the fluids and the transducer. For transducer #1390 used in this test, the output remains essentially constant as temperature changes when air and water are used. When methyl alcohol-ethylene glycol is used the transducer output decreases with increasing temperature. This supports the results presented in Table 2, which show that the difference between calculated and observed pressure changes decrease as the percent methyl alcohol-ethylene glycol in the mixture decreases. The magnitude of this fluid characteristic factor was determined from values presented in Table 2 and results are displayed in Figure 23, where the change in pressure transducer output is shown as a function of percent methyl alcohol-ethylene glycol.

### Recommendations

More comparisons of transducer response under field and laboratory conditions need to be conducted in order to establish correction procedures. Since 20 new transducers have been laboratory tested, if the sites and transducer serial numbers could be identified, the October 1987 SNOTEL data already collected could readily be analyzed. Also, some of the old transducers that were removed have been laboratory tested, and this data plus the June 1987 SNOTEL data could be compared. The addition of 8 to 12 new comparisons could aid considerably in establishing consistency of relationships and possible correction procedures.

### C. Statistical Analysis of SNOTEL Flutter Study Data

The 1985 flutter study data were scanned and a rerun was made on the stations where a rain free period of more than five observations could be obtained. Tables for each state have been prepared that are similar to the ones in the 1986 SNOTEL Annual Progress Report. However, the 1985 data proved to be so limited that no valid comparisons could be made between the 1985 and 1986 results. Properties of the 1985 data that severely limited their usefulness were:

1. Only two observations per day which does not adequately represent the diurnal temperature pattern necessary to characterize a precipitation temperature dependency.
2. Equipment changes that may have occurred between the 1985 and 1986 flutter study runs.
3. The widespread occurrence of precipitation during the 1985 run which greatly reduced the number of rain-free observations.

For these reasons, the statistical characterization of the temperature dependency of the SNOTEL precipitation measurements is confined to the 1986 flutter runs as reported in the 1986 annual progress report.

Frequency statistics from the 1986 flutter run were tabulated and are included as Tables 16 through 25. The specification error band was recalculated and the statistics concerned with specification conformance are based on the recalculated error band. The revised tables are also included in this progress report, one for each state (Tables 26-34).

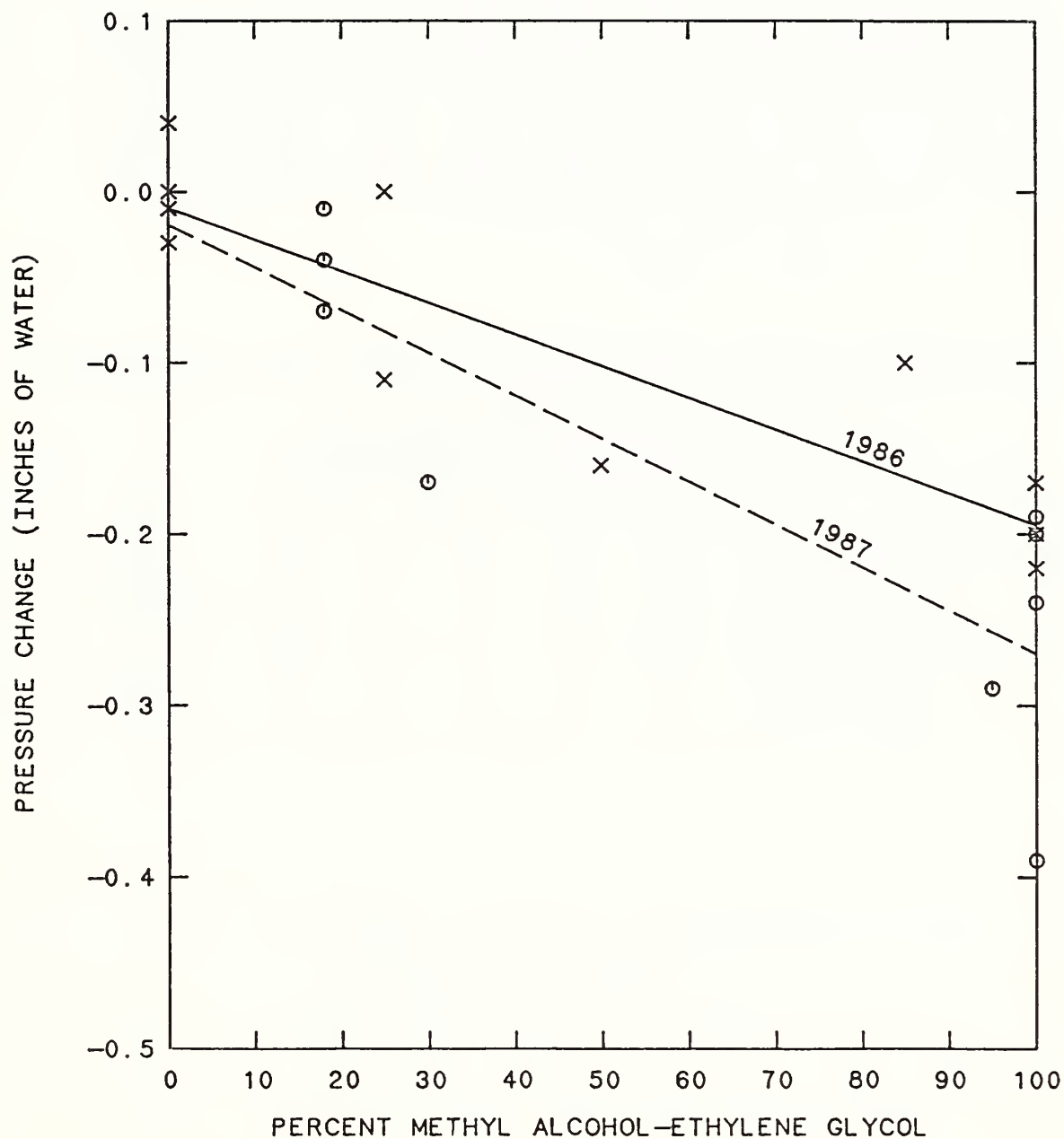


Figure 23. Pressure change in inches of water as a function of percent methyl alcohol-ethylene glycol in mixture, during two summers at the simulated SNOTEL site near the Boise Federal Building. The pressure change shown is the difference between observed and calculated pressure change for the simulated system.

Table 16. Frequency statistics from the 1986 flutter study for Arizona.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	10	59	7	41	17	100
+ correlation	4	40	1	14	5	29
- correlation	6	60	6	86	12	71
Random Prob < 0.02	6	67	3	33	9	53
+ correlation	3	50	0	0	3	33
- correlation	3	50	3	100	6	67

Table 17. Frequency statistics from the 1986 flutter study for Colorado.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	52	71	21	29	73	100
+ correlation	37	71	14	67	51	70
- correlation	15	29	7	33	22	30
Random Prob < 0.02	33	77	10	23	43	60
+ correlation	29	88	8	80	37	86
- correlation	4	12	2	20	6	14

Table 18. Frequency statistics from the 1986 flutter study for Idaho.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	42	67	21	33	63	100
+ correlation	18	43	9	43	27	43
- correlation	24	57	12	57	36	57
Random Prob < 0.02	27	63	16	37	43	68
+ correlation	13	48	6	37	19	44
- correlation	14	52	10	63	24	56

Table 19. Frequency statistics from the 1986 flutter study for Montana.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	64	96	3	4	67	100
+ correlation	17	27	1	33	18	27
- correlation	47	73	2	67	49	73
Random Prob < 0.02	25	89	3	11	28	42
+ correlation	3	12	1	33	4	14
- correlation	22	88	2	67	24	86

Table 20. Frequency statistics from the 1986 flutter study for Nevada.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	40	82	9	18	49	100
+ correlation	18	45	4	44	22	45
- correlation	22	55	5	56	27	55
Random Prob < 0.02	26	76	8	24	34	69
+ correlation	10	38	4	50	14	41
- correlation	16	62	4	50	20	59

Table 21. Frequency statistics from the 1986 flutter study for Oregon.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	40	58	29	42	69	100
+ correlation	16	40	17	59	33	48
- correlation	24	60	12	41	36	52
Random Prob < 0.02	23	46	27	54	50	72
+ correlation	8	35	16	59	24	48
- correlation	15	65	11	41	26	52

Table 22. Frequency statistics from the 1986 flutter study for Utah.

	Specification Error Band				Total	
	Inside Band		Outside Band			
	No.	Percent	No.	Percent	No.	Percent
Total	47	66	24	34	71	100
+ correlation	15	32	15	63	30	42
- correlation	32	68	9	37	41	58
Random Prob < 0.02	16	48	17	52	33	46
+ correlation	4	25	13	76	17	52
- correlation	12	75	4	24	16	48

Table 23. Frequency statistics from the 1986 flutter study for Washington.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	25	69	11	31	36	100
+ correlation	10	40	8	73	18	50
- correlation	15	60	3	27	18	50
Random Prob < 0.02	15	60	10	40	25	69
+ correlation	5	33	8	80	13	52
- correlation	10	67	2	20	12	48

Table 24. Frequency statistics from the 1986 flutter study for Wyoming.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	49	68	23	32	72	100
+ correlation	21	43	11	48	32	44
- correlation	28	57	12	52	40	56
Random Prob < 0.02	21	57	16	43	37	51
+ correlation	9	43	10	63	19	51
- correlation	12	57	6	38	18	49

Table 25. Frequency statistics from the 1986 flutter study for all sites.

	Specification Error Band					
	Inside Band		Outside Band		Total	
	No.	Percent	No.	Percent	No.	Percent
Total	369	71	148	29	517	100
+ correlation	156	42	80	54	236	46
- correlation	213	58	68	46	281	54
Random Prob < 0.02	192	64	110	36	302	58
+ correlation	84	44	66	60	150	50
- correlation	108	56	44	40	152	50

TABLE 26. REVISED PRECIPITATION-TEMPERATURE 1986 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN ARIZONA.

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	AUGUST 1986 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
9	RH10	BAKER BUTTE	18-23	24	0.709	0.01	25.54	25.40	0.30	22.33	13.80	18.30	-0.261	0.012	25.32	25.76
11	RH10	BALDY	18-26	34	-0.014	93.55	23.36	23.10	0.70	11.49	3.30	19.00	0.001	0.000	23.07	23.65*
69	RH10	BUCK SPRING	18-23	22	-0.709	0.02	24.70	24.50	0.30	16.97	2.40	25.70	0.152	-0.009	24.39	25.01
111	RH10	CORONADO TRAIL	18-27	36	-0.404	1.45	28.72	23.60	6.20	14.56	6.10	20.30	1.454	-0.100	28.39	29.05*
177	RH10	FRISCO DIVIDE	18-24	22	0.141	53.13	19.81	19.50	0.50	16.53	8.00	19.40	-0.051	0.003	19.60	20.02*
179	RH05	FRY	18-22	22	-0.873	<.01	25.75	25.60	0.30	19.30	9.20	22.20	0.200	-0.010	25.48	26.02
202	PR10	HANNAGAN MEADOWS	18-28	41	-0.319	4.22	24.00	23.30	1.60	12.41	4.70	20.50	0.398	-0.032	23.71	24.29*
208	RH05	HEBER	18-25	25	0.311	13.02	24.69	24.60	0.20	20.10	13.10	19.90	-0.066	0.003	24.47	24.91
281	RH10	LOOKOUT MOUNTAIN	18-22	22	-0.919	<.01	22.05	21.90	0.30	20.38	12.60	18.00	0.338	-0.016	21.85	22.25
298	PR10	MAVERICK FORK	18-25	31	-0.267	14.65	18.38	18.20	0.40	12.19	3.20	19.20	0.051	-0.004	18.15	18.61
316	RH05	MORMON MOUNTAIN	18-28	37	-0.250	13.58	27.59	26.80	2.90	16.15	9.30	17.20	0.504	-0.031	27.31	27.87*
422	RH10	SIGNAL PEAK	18-22	15	0.617	1.42	35.29	35.10	0.40	17.76	11.70	14.50	-0.264	0.015	34.96	35.62
424	RH10	SILVER CREEK DIVIDE	18-25	29	0.580	0.09	31.46	31.30	0.30	13.18	5.20	17.10	-0.136	0.010	31.09	31.83
459	RH10	SUGAR LOAF	18-23	25	-0.932	<.01	17.94	17.50	0.90	23.12	12.10	19.50	0.987	-0.043	17.77	18.11*
512	RH05	WHITE HORSE LAKE	18-22	14	-0.597	2.41	21.18	21.10	0.20	19.51	10.90	20.30	0.122	-0.006	20.97	21.39
517	RH05	WILDCAT	18-23	22	-0.296	18.11	28.40	28.30	0.20	15.87	4.70	21.90	0.044	-0.003	28.06	28.74
527	RH10	WORKMAN CREEK	18-22	15	-0.814	0.02	32.51	32.30	0.50	21.57	13.50	16.90	0.509	-0.024	32.23	32.79*

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 27. REVISED PRECIPITATION-TEMPERATURE 1986 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN COLORADO (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	AUGUST 1986 DATE	NOBS	P/T CORRELATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
360	RH05	PHANTOM VALLEY	18-20	12	0.911	<.01	29.88	29.70	0.40	16.35	4.60	22.60	-0.249	0.015	29.52	30.24
373	PR10	PORPHYRY CREEK	18-28	45	-0.236	11.91	26.04	25.20	1.60	9.97	2.00	18.20	0.217	-0.022	25.70	26.38*
380	RH05	QUEMAZON	18-26	11	0.005	98.93	28.82	27.60	2.10	16.05	9.70	15.50	-0.009	0.000	28.53	29.11*
384	RH10	REO MOUNTAIN PASS	25-28	12	0.895	<.01	43.03	42.70	0.60	8.01	3.30	12.10	-0.354	0.045	42.50	43.56
386	RH10	REO RIVER PASS #2	24-28	14	-0.352	21.77	19.67	19.60	0.30	8.99	1.10	15.10	0.071	-0.008	19.41	19.93
388	RH10	ROACH	22-27	22	0.800	<.01	40.60	40.50	0.30	11.55	0.00	18.80	-0.174	0.015	40.05	41.15
407	RH10	SCHOFIELO PASS	25-28	15	0.935	<.01	59.97	59.80	0.40	7.95	2.80	13.30	-0.196	0.024	59.21	60.73
409	RH10	SCOTCH CREEK	24-28	15	0.535	4.00	1.41	1.40	0.10	11.27	3.20	18.60	-0.035	0.003	1.39	1.43*
413	RH05	SENORITA DIVIOE	18-23	16	-0.410	11.42	29.11	29.00	0.20	14.53	5.30	18.90	0.036	-0.003	28.77	29.45
430	RH05	SLUNGULLION	18-20	12	0.790	0.22	25.78	25.70	0.30	13.22	6.50	14.70	-0.168	0.013	25.49	26.07
454	RH10	STILLWATER CREEK	21-28	31	0.933	<.01	20.61	20.40	0.50	11.94	3.60	18.10	-0.323	0.027	20.36	20.86*
462	PR10	SUMMIT RANCH	18-20	10	-0.258	47.14	23.77	23.70	0.10	15.15	5.40	20.60	0.025	-0.002	23.49	24.05
478	RH10	TOWER	21-24	16	-0.944	<.01	66.36	66.30	0.10	11.04	5.70	10.00	0.135	-0.013	65.59	67.13
480	RH10	TRAPPER LAKE	24-28	15	0.646	0.93	37.19	37.00	0.40	10.24	1.30	18.50	-0.119	0.012	36.70	37.68
491	PR10	UNIVERSITY CAMP	18-19	8	0.903	0.21	37.95	37.90	0.10	15.24	7.40	14.50	-0.128	0.008	37.53	38.37
492	PR10	UPPER SAN JUAN	21-23	10	-0.316	37.38	62.86	62.80	0.10	11.53	4.20	14.70	0.037	-0.003	62.10	63.62
494	RH10	VAIL MOUNTAIN	18-21	15	0.777	0.06	32.04	31.90	0.60	14.35	6.40	17.00	-0.383	0.027	31.68	32.40*
495	RH10	VALLECITO	26-28	7	0.127	78.58	18.31	16.00	4.20	8.93	5.40	8.60	-0.706	0.080	18.10	18.52*
499	RH05	W FORK PARACHUTE	21-24	14	0.837	0.01	23.84	23.80	0.10	13.77	4.60	17.90	-0.091	0.007	23.56	24.12
509	RH05	WHISKEY CK	18-28	26	-0.097	63.89	34.02	32.90	2.70	11.73	1.30	20.00	0.176	-0.015	33.57	34.47*
520	PR10	WILLOW CREEK PASS	21-27	11	-0.409	21.11	29.67	29.60	0.70	8.99	2.00	16.00	0.130	-0.014	29.29	30.05*
521	RH10	WILLOW PARK	22-28	20	0.710	0.04	43.37	43.00	1.00	7.72	-0.60	16.80	-0.310	0.040	42.77	43.97*
524	RH10	WOLF CREEK SUMMIT	22-23	6	0.808	5.19	14.37	14.20	0.30	11.08	6.00	9.40	-0.228	0.020	14.21	14.53*

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 28. REVISED PRECIPITATION-TEMPERATURE 1986 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN IOAHO (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	AUGUST 1986 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
420	RH10	SHERWIN	25-28	12	-0.790	0.22	31.46	31.10	0.70	20.39	6.10	26.90	0.404	-0.020	31.10	31.82*
429	RH10	SLUG CREEK OVIDE	23-28	18	0.362	13.98	43.31	42.70	0.80	15.56	8.20	17.70	-0.208	0.013	42.85	43.77*
434	RH05	SOMSEN RANCH	23-28	21	0.820	<.01	33.42	33.30	0.30	14.68	7.00	14.80	-0.251	0.017	33.05	33.79
437	RH15	SOUTH MTN.	18-20	12	0.682	1.45	34.45	34.20	0.60	22.70	17.60	14.30	-0.503	0.022	34.18	34.72*
444	RH10	SQUAW FLAT	22-28	24	-0.874	<.01	43.33	43.00	0.50	18.83	6.50	25.10	0.409	-0.022	42.84	43.82
453	RH10	STICKNEY MILL	22-28	19	-0.961	<.01	19.80	19.20	1.10	15.02	1.50	24.50	0.628	-0.042	19.54	20.06*
463	RH15	SUNSET	18-22	17	-0.963	<.01	49.21	48.60	1.20	18.71	11.90	14.00	1.527	-0.082	48.75	49.67*
465	RH20	SWEDE PEAK	18-21	12	0.286	36.76	30.73	30.60	0.30	17.95	10.50	18.50	-0.089	0.005	30.43	31.03
482	RH15	TRINITY MTN.	23-28	17	-0.855	<.01	62.89	62.60	0.40	12.70	4.40	18.70	0.230	-0.018	62.13	63.65
497	RH15	VIENNA MINE	23-28	16	0.751	0.07	48.51	48.40	0.40	16.52	9.00	16.80	-0.287	0.018	48.01	49.01
507	RH10	WEST BRANCH	22-28	24	-0.800	<.01	42.84	42.50	0.60	21.13	11.20	21.50	0.530	-0.025	42.43	43.25
511	RH10	WHITE ELEPHANT	25-28	12	0.879	0.01	55.98	55.90	0.20	16.27	10.40	13.70	-0.261	0.016	55.43	56.53
518	RH10	WILDHORSE OVIDE	22-28	27	0.453	1.75	35.39	34.80	1.60	17.99	8.60	21.80	-0.554	0.031	35.02	35.76*

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 29. REVISED PRECIPITATION-TEMPERATURE 1986 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN MONTANA (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	AUGUST 1986 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
392	PR10	ROCKER PEAK	22-28	24	-0.233	27.28	29.53	29.50	0.10	11.36	4.20	15.80	0.030	-0.002	29.17	29.89
395	PR10	S FORK SHIELDS	21-28	24	0.032	88.23	38.04	38.00	0.10	11.24	0.60	18.30	-0.002	0.000	37.53	38.55
397	PR10	SADDLE MTN.	23-28	13	0.455	11.84	35.88	35.80	0.10	14.16	6.30	20.70	-0.031	0.002	35.47	36.29
421	PR10	SHOWER FALLS	23-28	18	0.205	41.35	42.76	42.70	0.10	12.44	4.10	20.30	-0.022	0.001	42.24	43.28
425	PR10	SILVER RUN	22-28	24	-0.581	0.28	14.33	14.20	0.20	12.35	3.40	18.90	0.062	-0.005	14.15	14.51
427	PR10	SKALKAHO SUMMIT	22-28	18	-0.505	3.24	35.12	35.00	0.20	9.53	-0.40	21.70	0.051	-0.006	34.64	35.60
428	RH15	SKYLARK TRAIL	20-28	29	-0.742	<.01	45.14	45.00	0.30	16.58	9.80	16.90	0.242	-0.015	44.69	45.59
443	PR10	SPUR PARK	22-28	32	-0.593	0.03	35.67	35.60	0.10	11.28	-0.70	22.80	0.048	-0.005	35.18	36.16
448	RH15	STAHL PEAK	18-26	34	-0.077	66.32	52.14	52.00	0.30	12.82	1.60	20.90	0.018	-0.001	51.46	52.82
471	PR10	TEPEE CREEK	25-28	12	-0.205	52.23	26.14	26.10	0.10	15.02	8.40	16.70	0.027	-0.002	25.86	26.42
488	PR10	TWELVEMILE CREEK	22-28	18	0.464	5.22	42.86	42.80	0.20	15.24	1.40	26.00	-0.051	0.003	42.30	43.42
489	PR15	TWIN LAKES	21-28	28	-0.881	<.01	63.12	63.00	0.20	14.75	2.80	27.40	0.145	-0.009	62.32	63.92
500	PR10	WALDRON	20-28	24	-0.131	54.14	26.23	26.10	0.40	10.29	-0.60	25.10	0.015	-0.002	25.87	26.59
503	PR10	WARM SPRINGS	21-28	28	-0.150	44.66	43.32	43.30	0.10	8.65	-2.10	22.80	0.005	-0.001	42.70	43.94
510	PR10	WHISKEY CREEK	18-21	12	-0.613	3.40	36.64	36.60	0.20	12.82	-2.90	30.10	0.062	-0.005	36.10	37.18
513	PR10	WHITE MILL	22-28	23	-0.042	84.78	42.92	42.80	0.20	9.37	-2.70	26.50	0.005	0.000	42.29	43.55
526	PR10	WOOD CREEK	22-28	25	-0.473	1.68	25.49	25.40	0.10	16.38	4.30	23.20	0.033	-0.002	25.18	25.80

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.





TABLE 31. REVISED PRECIPITATION-TEMPERATURE 1986 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN OREGON (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	AUGUST 1986 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
389	PR10	ROARING RIVER	18-28	42	0.861	<.01	69.64	69.00	1.30	23.12	12.80	21.00	-1.510	0.065	69.01	70.27*
391	RH10	ROCK SPRINGS	18-21	12	-0.710	0.96	15.17	15.10	0.10	20.39	8.40	24.40	0.076	-0.003	15.01	15.33
396	RH20	SADDLE MOUNTAIN	18-28	47	-0.875	<.01	75.59	74.70	1.50	19.66	8.90	20.60	1.472	-0.075	74.80	76.38*
399	RH15	SALT CREEK FALLS	18-28	48	-0.904	<.01	63.61	62.90	1.30	19.45	9.40	19.00	1.158	-0.059	62.96	64.26*
403	RH15	SANTIAM JCT.	18-28	42	0.124	43.24	67.75	67.30	0.70	18.86	2.20	31.00	-0.050	0.003	66.88	68.62
406	RH10	SCHNEIDER MEADOWS	18-22	11	0.551	7.89	48.81	48.50	0.60	14.12	4.50	21.40	-0.194	0.014	48.23	49.39
412	RH20	SEINE CREEK	18-28	48	0.485	0.04	58.44	53.70	6.80	17.33	0.40	27.50	-2.438	0.141	57.65	59.23*
423	RH10	SILVER CREEK	18-28	33	0.834	<.01	25.30	24.50	1.90	19.52	7.30	24.00	-1.529	0.079	25.02	25.58*
426	RH10	SILVIES	18-28	20	-0.145	54.16	15.53	15.40	0.20	19.56	10.30	16.80	0.024	-0.001	15.38	15.68
433	PR15	SNOW MOUNTAIN	18-28	39	-0.768	<.01	26.05	25.90	0.40	18.09	7.40	18.90	0.270	-0.015	25.77	26.33
450	RH10	STARR RIDGE	18-23	24	0.659	0.04	19.11	19.00	0.30	21.55	10.20	22.70	-0.218	0.010	18.92	19.30*
455	PR10	STRAWBERRY	18-25	34	0.829	<.01	20.17	20.00	0.30	19.81	8.60	21.80	-0.264	0.013	19.96	20.38
460	PR10	SUMMER RIM	25-28	12	0.702	1.09	27.57	25.40	4.60	11.35	5.70	12.90	-2.429	0.214	27.25	27.89*
461	RH15	SUMMIT LAKE	18-28	44	0.156	31.05	1.54	-14.20	32.00	15.70	-0.60	33.00	-2.539	0.162	1.52	1.56*
468	RH10	TAYLOR BUTTE	18-28	42	0.088	57.94	21.85	21.70	0.30	18.82	3.80	28.80	-0.012	0.001	21.58	22.12
470	RH15	TAYLOR GREEN	18-28	44	-0.318	3.52	36.86	36.00	1.40	20.13	10.00	20.90	0.417	-0.021	36.49	37.23*
472	RH15	THREE CREEKS MEADOW	18-28	34	-0.041	81.91	36.56	36.40	0.30	16.87	6.40	22.30	0.013	0.000	36.15	36.97
474	RH10	TIPTON	18-23	23	0.757	<.01	25.13	24.90	0.70	19.97	8.10	23.90	-0.598	0.030	24.86	25.40*
523	PR10	WOLF CREEK	24-28	16	-0.444	8.52	22.71	22.70	0.10	31.88	20.10	24.70	0.046	-0.002	22.43	22.99

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 32. REVISED PRECIPITATION-TEMPERATURE 1986 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN UTAH (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	AUGUST 1986		P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
			DATE	NOBS			AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
278	RH10	LONG FLAT	22-28	21	0.651	0.13	18.48	17.90	1.40	16.52	8.30	14.10	-0.992	0.060	18.28	18.68*
279	PR10	LONG VALLEY JCT	24-28	20	-0.151	52.59	3.26	3.20	0.10	16.02	9.20	17.00	0.022	-0.001	3.23	3.29*
293	PR10	MAMMOTH-COTTONWOOD	25-28	16	-0.387	13.81	30.63	30.50	0.20	12.73	3.30	19.80	0.049	-0.004	30.25	31.01
302	RH10	MERCHANT VALLEY	25-28	12	0.346	27.11	29.93	29.90	0.10	13.03	4.70	19.10	-0.030	0.003	29.57	30.29
305	RH10	MIDWAY VALLEY	21-25	15	0.623	1.30	37.27	37.20	0.20	10.23	3.60	13.70	-0.098	0.009	36.81	37.73
310	PR10	MONTE CRISTO	21-28	29	-0.177	35.83	51.51	51.40	0.20	11.50	5.10	15.70	0.034	-0.003	50.90	52.12
318	RH10	MOSBY MTN.	21-28	29	-0.934	<.01	-6.09	-6.40	0.60	13.46	6.00	15.80	0.413	-0.031	-6.02	-6.16*
357	PR10	PARLEY'S SUMMIT	24-28	14	0.164	57.64	38.19	38.10	0.10	20.71	13.00	15.50	-0.015	0.001	37.85	38.53
358	PR10	PAYSON R.S.	21-26	22	-0.675	0.05	35.00	34.80	0.50	14.91	8.60	14.30	0.277	-0.018	34.63	35.37
363	PR10	PICKLE KEG	21-26	19	0.145	55.49	30.03	30.00	0.10	12.19	6.00	11.50	-0.022	0.002	29.69	30.37
366	RH10	PINE CREEK	24-27	13	-0.610	2.69	31.19	31.10	0.20	16.15	8.60	18.10	0.076	-0.005	30.86	31.52
385	PR10	RED PINE RIDGE	24-28	16	-0.930	<.01	33.82	33.50	0.70	12.18	2.80	19.40	0.476	-0.039	33.39	34.25
390	RH10	ROCK CREEK	23-28	20	-0.823	<.01	30.19	29.80	0.70	12.48	5.80	15.10	0.475	-0.038	29.84	30.54*
393	PR10	ROCKY BASIN-SETTLEME	21-25	18	-0.172	49.50	48.31	48.30	0.10	15.70	10.20	14.30	0.011	-0.001	47.83	48.79
411	PR10	SEELEY CREEK	18-28	45	-0.068	65.99	28.00	27.90	0.10	-4.82	-12.50	30.80	-0.005	0.000	27.49	28.51
431	PR10	SMITH & MOREHOUSE	22-28	25	0.379	6.15	43.00	42.90	0.20	16.61	4.60	23.50	-0.038	0.002	42.49	43.51
451	PR10	STEEL CREEK PARK	21-24	12	0.606	3.65	34.44	34.40	0.10	4.62	0.70	10.00	-0.044	0.010	33.98	34.90
456	PR10	STRAWBERRY DIVIDE	20-28	33	-0.129	47.42	38.09	38.00	0.20	19.21	9.30	21.30	0.017	-0.001	37.70	38.48
473	RH10	TIMPANOGOS DIVIDE	22-28	22	-0.754	<.01	52.45	51.80	1.10	18.09	10.70	15.00	0.896	-0.049	51.94	52.96*
476	PR10	TONY GROVE LAKE	22-28	24	-0.491	1.48	67.02	67.00	0.10	16.52	6.70	20.60	0.055	-0.004	66.27	67.77
481	PR10	TRIAL LAKE	23-28	24	0.278	18.80	58.00	57.90	0.10	9.91	2.90	15.70	-0.015	0.001	57.27	58.73
486	RH10	TROUT CREEK	24-28	18	-0.402	9.82	-3.07	-3.40	0.50	36.34	4.40	52.80	0.136	-0.004	-3.02	-3.12*
496	PR10	VERNON CREEK	22-25	15	-0.503	5.57	29.63	29.50	0.20	21.23	15.10	14.90	0.162	-0.008	29.39	29.87
506	PR10	WEBSTER FLAT	24-27	13	-0.159	60.45	29.56	29.50	0.10	17.26	10.40	15.10	0.030	-0.002	29.27	29.85
515	PR10	WHITE RIVER #1	23-25	11	-0.248	46.19	27.75	27.70	0.10	14.84	5.40	16.70	0.030	-0.002	27.43	28.07
516	PR10	WILOSTOE #3	23-28	20	-0.428	5.94	20.02	19.90	0.30	-2.80	-10.50	32.30	-0.008	-0.003	19.67	20.37

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

TABLE 33. REVISED PRECIPITATION-TEMPERATURE 1986 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN WASHINGTON.

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	AUGUST 1986 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
52	RH15	BLEWETT PASS	23-25	10	0.895	0.04	34.64	34.30	0.90	16.49	10.70	15.40	-0.961	0.058	34.30	34.98*
72	RH25	BUMPING RIDGE	20-26	25	0.937	<.01	57.73	57.50	0.50	16.91	7.90	20.30	-0.532	0.031	57.11	58.35
73	RH15	BUNCHGRASS MDW	18-21	16	-0.614	1.14	44.53	44.20	0.60	15.93	-1.00	27.90	0.289	-0.018	43.91	45.15
113	RH15	CORRAL PASS	20-28	27	-0.926	<.01	53.60	53.30	0.60	16.13	6.20	20.20	0.447	-0.028	52.99	54.21
115	RH15	COUGAR MOUNTAIN	18-27	21	0.256	26.34	86.30	86.10	0.40	16.31	10.30	14.60	-0.105	0.006	85.45	87.15
169	RH15	FISH LAKE	18-28	41	0.902	<.01	49.54	49.20	0.80	15.34	3.20	25.00	-0.398	0.026	48.92	50.16
192	RH10	GREEN LAKE	18-28	37	-0.040	81.44	33.23	33.20	0.10	16.80	8.40	17.80	0.003	0.000	32.88	33.58
197	RH10	GROUSE CAMP	18-24	27	-0.395	4.13	30.67	30.60	0.10	17.40	9.40	15.40	0.067	-0.004	30.36	30.98
205	RH20	HARTS PASS	21-26	19	-0.015	95.01	78.09	77.80	0.50	13.05	6.10	16.00	0.005	0.000	77.20	78.98
241	RH25	JUNE LAKE	18-28	46	-0.693	<.01	138.98	138.70	0.60	19.93	9.50	20.70	0.448	-0.022	137.56	140.40
277	RH25	LONE PINE	18-28	41	-0.684	<.01	77.01	76.70	0.80	16.06	8.40	15.70	0.566	-0.035	76.20	77.82
289	RH25	LYMAN LAKE	18-25	32	0.369	3.78	63.12	62.80	0.50	17.08	6.80	22.90	-0.154	0.009	62.42	63.82
308	RH20	MIRROR LAKE	18-28	37	-0.713	<.01	36.43	35.50	1.60	13.16	4.80	18.80	0.719	-0.055	36.00	36.86*
317	RH20	MORSE LAKE	18-26	34	0.758	<.01	70.94	70.10	2.00	17.89	9.40	17.40	-1.545	0.086	70.21	71.67*
347	RH25	OLALLIE MEADOWS	18-28	29	-0.702	<.01	103.84	103.70	0.30	16.72	7.60	21.20	0.204	-0.012	102.71	104.97
352	RH25	PARADISE	18-25	30	0.690	<.01	102.28	102.20	0.20	15.72	7.50	19.20	-0.140	0.009	101.16	103.40
354	RH15	PARK CREEK RIDGE	18-28	41	0.485	0.13	57.83	57.10	1.30	14.61	6.60	20.30	-0.620	0.042	57.18	58.48*
364	RH15	PIGTAIL PEAK	18-28	34	0.567	0.04	64.20	6.70	150.00	3.16	-50.00	100.00	-2.696	0.854	62.17	66.23*
368	RH25	PLAINS OF ABRAHAM	18-28	48	-0.706	<.01	102.84	102.60	0.50	18.98	10.30	18.90	0.270	-0.014	101.82	103.86
371	RH10	POPE RIDGE	18-28	38	-0.705	<.01	-3.32	-3.50	0.40	18.58	5.40	25.30	0.198	-0.010	-3.28	-3.36*
374	RH25	POTATO HILL	22-28	25	-0.184	37.88	53.79	51.10	6.40	17.01	3.60	25.30	0.957	-0.056	53.13	54.45*
379	RH10	QUARTZ PEAK	18-28	37	0.725	<.01	5.96	5.90	0.20	20.75	11.90	16.60	-0.187	0.009	5.90	6.02*
382	RH15	RAINY PASS	20-27	29	0.812	<.01	-5.98	-6.10	0.30	13.64	4.80	18.90	-0.194	0.014	-5.91	-6.05*
398	PR15	SALMON MEADOWS	18-22	17	0.446	7.30	16.74	16.60	0.20	17.98	4.90	21.50	-0.075	0.004	16.54	16.94
404	RH15	SASSE RIDGE	18-28	42	-0.380	1.31	51.41	51.30	0.30	21.61	10.00	24.00	0.102	-0.005	50.90	51.92
417	RH20	SHEEP CANYON	18-24	32	-0.165	36.54	104.08	103.90	0.40	17.68	8.70	17.40	0.061	-0.004	102.99	105.17
439	RH15	SPENCER MEADOW	18-28	47	0.705	<.01	81.41	81.20	0.80	22.54	8.90	27.80	-0.478	0.021	80.56	82.26
440	RH10	SPIRIT LAKE	18-26	35	0.136	43.52	92.05	91.90	0.60	16.39	7.90	19.80	-0.053	0.003	91.06	93.04
449	RH25	STAMPEDE PASS	24-28	7	-0.699	8.05	80.17	79.50	1.30	17.13	10.40	16.70	1.178	-0.069	79.38	80.96
452	RH20	STEVENS PASS	21-28	25	-0.892	<.01	77.77	77.20	1.10	17.77	8.50	22.20	0.738	-0.042	76.95	78.59
457	RH25	STRAWBERRY LANDING	21-28	32	-0.605	0.02	80.32	79.60	1.30	17.24	8.90	18.60	0.882	-0.051	79.48	81.16
464	RH25	SURPRISE LAKES	18-28	43	-0.895	<.01	81.50	81.00	0.80	26.25	14.50	26.60	0.639	-0.024	80.59	82.41
477	RH10	TOUCHET #2	18-25	30	0.851	<.01	48.20	48.10	0.30	18.96	12.40	18.00	-0.344	0.018	47.76	48.64
484	RH10	TROUGH	20-25	18	0.769	0.01	32.80	32.30	1.20	15.89	9.00	14.30	-1.078	0.068	32.46	33.14*
493	RH10	UPPER WHEELER	18-28	41	0.560	0.01	25.09	24.60	1.30	20.16	9.60	20.60	-0.631	0.031	24.84	25.34*
514	PR10	WHITE PASS E.	19-22	13	0.110	71.94	36.35	36.30	0.10	18.53	9.60	15.50	-0.022	0.001	35.98	36.72

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 34. REVISED PRECIPITATION-TEMPERATURE 1986 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN WYOMING (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	AUGUST 1986 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
401	RH10	SAND LAKE	24-28	20	0.350	13.01	45.00	44.90	0.20	9.06	0.00	19.30	-0.027	0.003	44.39	45.61
402	RH10	SANOSTONE RS	21-28	33	-0.756	<.01	30.53	30.30	0.40	13.95	5.30	17.10	0.231	-0.017	30.17	30.89
419	PR10	SHELL CREEK	22-28	25	-0.183	38.00	25.41	25.40	0.10	4.59	-4.60	19.20	0.002	-0.001	25.02	25.80
432	RH10	SNIOER BASIN	21-26	22	0.849	<.01	31.33	30.90	0.80	14.18	1.40	21.50	-0.454	0.032	30.92	31.74*
436	PR10	SOUTH BRUSH CREEK	18-20	12	0.329	29.67	28.04	28.00	0.10	14.21	5.10	22.20	-0.034	0.003	27.71	28.37
438	PR10	SOUTH PASS	21-24	14	-0.378	18.28	45.07	45.00	0.20	11.79	3.70	16.20	0.047	-0.004	44.52	45.62
442	PR10	SPRING CREEK DIVIOE	21-25	19	0.252	29.73	50.19	50.00	0.20	12.45	5.20	13.20	-0.034	0.003	49.60	50.78
446	PR10	ST. LAWRENCE	18-24	26	0.211	30.16	27.10	27.10	0.10	13.10	2.00	28.40	-0.003	0.001	26.75	27.45
447	PR10	ST. LAWRENCE ALT	18-20	10	-0.409	24.00	20.91	20.90	0.10	17.82	8.40	21.10	0.029	-0.002	20.69	21.13
458	PR10	SUCKER CREEK	18-28	46	0.389	0.75	27.13	27.10	0.20	11.90	0.00	24.10	-0.043	0.003	26.76	27.50
466	PR10	SYLVAN LAKE	21-25	16	-0.700	0.25	40.16	40.10	0.10	8.80	-1.90	22.20	0.043	-0.005	39.59	40.73
475	RH10	TOGWOTEE PASS	18-21	13	0.553	4.99	43.17	43.10	0.10	11.69	3.60	18.60	-0.054	0.005	42.64	43.70
479	PR10	TOWNSEND CREEK	18-20	10	-0.365	29.91	27.43	27.30	0.20	16.34	4.70	23.70	0.043	-0.003	27.10	27.76
483	RH10	TRIPLE PEAK	24-28	17	0.929	<.01	51.29	50.90	1.00	11.77	2.80	19.40	-0.702	0.059	50.64	51.94
485	PR10	TROUT CK	22-26	16	0.717	0.17	24.72	24.70	0.10	11.39	4.10	19.80	-0.055	0.005	24.42	25.02
490	RH15	TWO OCEAN PLATEAU	18-28	41	-0.814	<.01	45.21	27.20	29.90	10.40	-0.50	23.40	10.410	-1.001	44.59	45.83*
504	PR10	WARREN PEAK	18-28	44	-0.664	<.01	24.58	24.50	0.10	15.77	6.10	24.20	0.062	-0.004	24.30	24.86
505	RH10	WEBBER SPRINGS	18-24	20	0.912	<.01	39.14	28.30	16.90	0.04	-18.30	44.30	-0.017	0.338	38.35	39.93*
519	RH10	WILLOW CREEK	25-28	15	0.114	68.50	62.65	62.60	0.10	15.89	9.50	13.40	-0.024	0.001	62.01	63.29
522	RH05	WINOY PEAK	18-28	42	0.867	<.01	24.36	24.00	0.90	15.89	3.60	30.00	-0.553	0.035	24.06	24.66*
525	PR10	WOLVERINE	23-28	21	0.610	0.33	29.20	28.60	1.40	12.42	2.00	22.20	-0.441	0.035	28.82	29.58*
528	PR10	YOUNTS PEAK	18-28	31	-0.185	31.92	34.07	33.50	1.30	10.19	0.50	24.90	0.138	-0.013	33.61	34.53*

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

The error band shown in the 1986 annual report was based on a temperature adjustment for the deviation of the mean temperature from 75 degrees F. This resulted in a narrower band than the actual specifications allowed. The recalculated error band was based on the maximum of the absolute deviation of the minimum or maximum temperature from 75 degrees F. This change in defining the error band resulted in reducing the number of stations failing to meet specifications from 203 (39%) to 148 (29%) of the 517 SNOTEL sites used in the 1986 flutter study.

The effectiveness of applying the correction equation to a site exhibiting a high temperature dependency was tested using the Moores Creek Summit raw SNOTEL data for the 1986 water year. Applying the correction equation to the raw data does attenuate the diurnal temperature effect, but does not eliminate it. The resulting corrected accumulated precipitation time series is not monotonic and remains inconsistent. However, it is much less so than the raw data series. This can be seen in figure 24.

Further refinement of the temperature correction equation was attempted by selecting additional rain-free periods from the 1986 water year raw data file. This produced four additional equations which, with the flutter study equation, make a total of five correction equations for the Moores Creek site. They are summarized as follows:

1. The 1986 flutter study equation derived from the 6 day period, 8/18/86 to 8/24/86 of 24 observations. (Correction equation in the Annual Report.)

$$C_1 = -0.905 + 0.053 T$$

$$r = +0.857 \quad RSQ = 0.734$$

$$PAVE = 55.59 \text{ inches} \quad \text{Range} = [55.0, 56.5] \quad \text{Delta} = 1.5 \text{ inches}$$

$$TAVE = 17.15 \text{ deg C.} \quad \text{Range} = [6.7, 31.0] \quad \text{Delta} = 24.3 \text{ deg C.}$$

2. Equation derived from the raw data series for the 40 day period, 6/13/86 to 7/23/86, consisting of 72 observations.

$$C_2 = -1.460 + 0.104 T$$

$$r = +0.931 \quad RSQ = 0.867$$

$$PAVE = 54.72 \text{ inches} \quad \text{Range} = [53.2, 56.3] \quad \text{Delta} = 3.1 \text{ inches}$$

$$TAVE = 14.09 \text{ deg C.} \quad \text{Range} = [-0.6, 29.2] \quad \text{Delta} = 29.8 \text{ deg C.}$$

3. Equation derived from the raw data series for the 30 day period, 7/26/86 to 8/24/86, consisting of 33 observations.

$$C_3 = -1.036 + 0.089 T$$

$$r = +0.920 \quad RSQ = 0.846$$

$$PAVE = 55.23 \text{ inches} \quad \text{Range} = [54.8, 56.6] \quad \text{Delta} = 1.8 \text{ inches}$$

$$TAVE = 11.63 \text{ deg C.} \quad \text{Range} = [5.9, 24.6] \quad \text{Delta} = 18.7 \text{ deg C.}$$

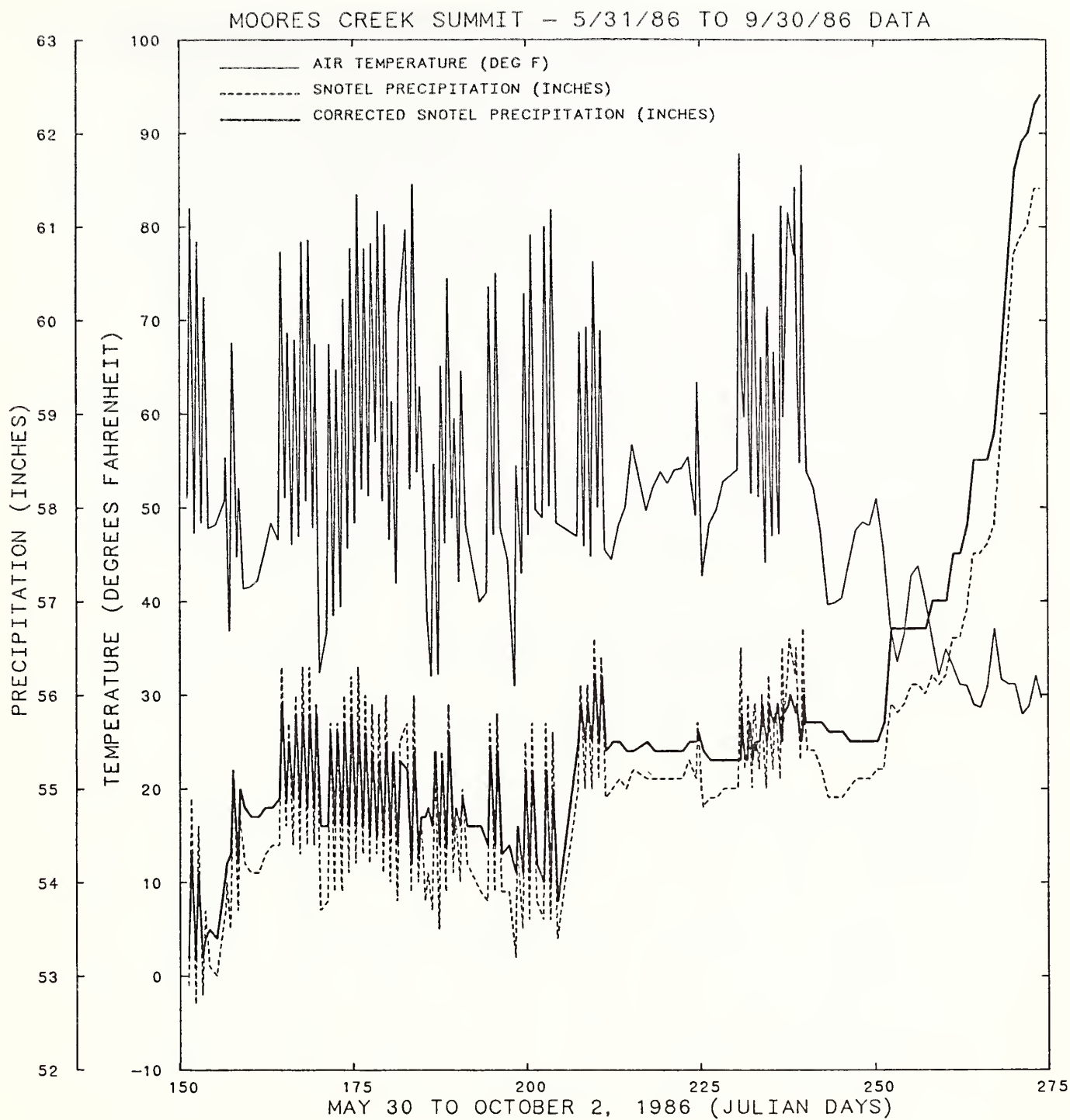


Figure 24. SNOTEL air temperature, precipitation, and precipitation corrected by equation C1 for the Moores Creek Summit during the time period from May 31 to September 30, 1986.

4. Equation derived from the raw data series for the 30 day period, 7/26/86 to 8/24/86, augmented by the flutter study data making a total of 50 observations.

$$C_4 = -0.985 + 0.068 T$$

$$r = +0.894 \quad RSQ = 0.800$$

PAVE = 55.42 inches    Range = [54.8, 56.6]    Delta = 1.8 inches  
TAVE = 14.46 deg C.    Range = [ 5.9, 31.0]    Delta = 25.1 deg C.

5. Equation derived from the raw data series for the 43 day period, 7/26/86 to 9/8/86, augmented by the flutter study data making a total of 64 observations.

$$C_5 = -0.784 + 0.060 T$$

$$r = +0.876 \quad RSQ = 0.767$$

PAVE = 55.36 inches    Range = [54.8, 56.6]    Delta = 1.8 inches  
TAVE = 12.97 deg C.    Range = [-2.1, 31.0]    Delta = 33.1 deg C.

Table 35 provides a comparison of values obtained by applying the five different correction equations to the raw precipitation measurements. T is the air temperature at the SNOTEL site in degrees Celsius, P is the raw SNOTEL precipitation reading,  $P_{ED}$  is the precipitation value from the edited Moores Creek data file obtained from the SCS.

Table 35. Comparison of SNOTEL precipitation as corrected by equations C1 through C5.

DATE	T	P	ACCUMULATED PRECIPITATION					$P_{ED}$
			$P_{C1}$	$P_{C2}$	$P_{C3}$	$P_{C4}$	$P_{C5}$	
10/02/85	2.2	0.1	0.9	1.3	0.9	0.9	0.8	0.0
06/01/86	8.5	52.7	53.2	53.3	53.0	53.1	53.0	52.9
09/01/86	4.3	54.9	55.6	55.9	55.6	55.6	55.4	55.4
09/30/86	-1.3	61.4	62.4	63.0	62.4	62.5	62.3	61.4
PERIOD		P	PRECIPITATION DURING PERIOD					$P_{ED}$
			$P_{C1}$	$P_{C2}$	$P_{C3}$	$P_{C4}$	$P_{C5}$	
10/02/85-09/30/86		61.3	61.5	61.7	61.5	61.6	61.5	61.4
10/02/85-06/01/86		52.6	52.3	52.0	52.1	52.2	52.2	52.9
06/01/86-09/01/86		2.2	2.4	2.6	2.6	2.5	2.4	2.5
09/01/86-09/30/86		6.5	6.8	7.1	6.8	6.9	6.9	6.0

The precipitation temperature correlation was positive for all of the five Moores Creek data sets and each equation produced a corrected time series similar to that shown in the Figure 24. Although the number 2 equation derived from the 40 day period with 72 observations produced the largest corrections and highest correlation, the first equation is nearly as effective. In addition, since the first equation was derived from a data set that represented the diurnal temperature pattern best, it remains the equation of choice.

Assessment of the 1986 results may be summarized as follows:

1. The transducer selection and installation procedures used by the various states need to be reviewed. This may help to explain why only four percent of the Montana sites failed the transducer specifications as contrasted with 42 percent in Oregon and an overall failure rate of 29 percent.
2. There was a highly significant precipitation temperature dependency at 58 percent of the 517 sites. Fifty percent of these showed a positive correlation and fifty percent were negatively correlated. Thermal expansion of the gaging system materials may explain some of the negative cases as noted in Section A, but the positive cases point to the transducers.
3. The correction equations derived from the regression analysis may remove some of the temperature dependency, but will still leave some inconsistency in the measured precipitation time series. How well they perform and their suitability for application can only be assessed after the causes of the anomalous behavior of the precipitation measurements have been firmly established.
4. The transducer specifications allow such a broad tolerance, greater than 1.0 inches of water, that these transducers may not be capable of providing measurements of the accuracy needed for some of the desired applications.

The flutter study was continued into 1987 by polling the sites from June 1 to June 10. Precipitation was quite widespread over the area during the last five days of the polling so all of the data for all of the sites had to be plotted and examined in order to select an appropriate rain-free period for the analysis. In general, this caused the analysis to be limited to only the first five days of the polling period. A summary of these analyses is included as Tables 36 through 45.

Several sites from each state were selected for transducer replacement after which another poll was made in order to isolate the transducer effects from other site effects. Table 46 shows which sites were selected as candidates for transducer replacement. The criteria used for making this selection were the correlation between precipitation and temperature, the precipitation range (delta) shown during the poll, and the probability of the relationship being non-significant.

The summary table for the poll conducted in October, 1987, following the replacement of some of the transducers is included as Table 47.

TABLE 36. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN ARIZONA.

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987		P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
			DATE	NOBS			AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
9	RH10	BAKER BUTTE	1- 3	16	0.749	0.08	24.78	24.60	0.40	21.84	9.70	21.50	-0.391	0.018	24.53	25.03
11	PR10	BALDY	1- 3	13	0.236	43.71	20.34	2.10	21.40	10.11	-0.30	19.00	-2.284	0.226	20.06	20.62*
71	RH05	BUCK SPRING	1- 3	14	0.116	69.21	23.36	23.30	0.20	11.82	-2.30	30.40	-0.004	0.001	23.02	23.70
114	RH10	CORONADO TRAIL	1- 3	11	0.963	<.01	21.59	21.20	0.70	13.12	-0.10	26.00	-0.340	0.026	21.30	21.88*
181	RH10	FRISCO DIVIDE	1- 3	7	-0.927	0.26	14.67	14.50	0.50	16.06	6.40	18.70	0.338	-0.021	14.50	14.84*
183	RH05	FRY	1- 3	14	-0.895	<.01	17.75	17.40	0.70	19.46	2.70	27.90	0.415	-0.021	17.53	17.97*
206	PR10	HANNAGAN MEADOWS	1- 3	13	0.216	47.87	22.45	22.40	0.10	12.97	-0.50	22.70	-0.017	0.002	22.14	22.76
212	RH05	HEBER	1- 3	14	-0.010	97.12	21.09	21.00	0.20	17.27	7.80	20.50	0.005	0.000	20.86	21.32
286	RH10	LOOKOUT MOUNTAIN	1- 3	13	0.401	17.42	13.87	13.60	1.90	19.34	7.90	23.60	-0.500	0.026	13.72	14.02*
303	PR10	MAVERICK FORK	1- 3	13	0.237	43.61	23.13	23.00	0.20	10.65	-2.30	21.20	-0.019	0.002	22.80	23.46
322	RH05	MORMON MOUNTAIN	1- 3	9	0.059	88.02	14.04	-30.30	49.90	14.71	5.10	19.30	-2.208	0.150	13.87	14.21*
383	RH10	PROMONTORY	1- 3	12	0.688	1.34	22.77	14.80	12.10	12.63	6.90	10.70	-13.071	1.035	22.52	23.02*
430	RH10	SIGNAL PEAK	1- 3	13	0.453	12.03	20.12	19.90	0.50	16.62	7.90	18.40	-0.201	0.012	19.90	20.34*
432	RH10	SILVER CREEK DIVIDE	1- 3	11	0.135	69.16	26.76	26.70	0.20	13.31	4.90	15.50	-0.019	0.002	26.44	27.08
470	RH10	SUGAR LOAF	1- 3	13	-0.926	<.01	15.45	15.20	0.60	19.78	4.20	27.00	0.464	-0.024	15.26	15.64*
525	RH05	WHITE HORSE LAKE	1- 3	13	0.354	23.55	-32.48	-32.50	0.10	17.56	5.30	23.70	-0.029	0.002	-32.10	-32.86*
530	RH05	WILDCAT	1- 3	12	0.047	88.49	23.14	23.00	0.20	13.40	1.20	20.50	-0.003	0.000	22.84	23.44
540		WORKMAN	1- 3	9	-0.900	0.09	24.31	24.00	0.60	18.26	8.20	19.70	0.469	-0.026	24.05	24.57*

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 37. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN COLORADO (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987 DATE	NOBS	P/T CORRELATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							Ave	Min	Delta	Ave	Min	Delta	a	b	Low	High
361	RH10	PARK RESERVOIR	1-	5	24	0.603	0.17	30.50	30.20	0.50	5.88	-6.20	21.10	-0.071	0.011	30.02, 30.98
366	RH05	PHANTOM VALLEY	1-	5	21	0.791	<.01	14.09	13.90	0.40	11.10	-2.50	27.20	-0.108	0.010	13.89, 14.29*
379	PR10	PORPHYRY CREEK	1-	5	21	-0.130	57.30	22.54	22.50	0.10	6.90	-4.20	21.10	0.010	-0.001	22.20, 22.88
386	RH05	QUEMAZON	1-	5	21	0.599	0.41	21.90	20.20	4.00	14.18	7.20	18.40	-2.213	0.156	21.66, 22.14*
391	RH10	RED MOUNTAIN PASS	1-	5	23	0.970	<.01	27.05	-17.80	51.90	0.96	-51.30	67.10	-0.774	0.803	26.18, 27.92*
393	RH05	RED RIVER PASS #2	1-	5	20	-0.327	15.97	15.82	15.70	0.50	11.09	2.10	17.80	0.075	-0.007	15.62, 16.02*
396	RH10	ROACH	1-	5	16	0.777	0.04	19.55	19.40	0.30	8.23	-5.20	28.50	-0.069	0.008	19.25, 19.85
415		SCHOFIELD PASS	1-	5	23	0.007	97.64	32.04	31.90	0.20	7.58	-2.90	21.10	-0.001	0.000	31.57, 32.51
417		SCOTCH CREEK	1-	5	22	0.746	<.01	27.16	26.90	0.50	10.01	-2.80	24.70	-0.135	0.014	26.76, 27.56
421	RH05	SENORITA DIVIOE	1-	5	15	0.033	90.66	9.27	-12.70	33.90	10.35	0.60	17.60	-0.753	0.072	9.15, 9.39*
438	RH05	SLUMGULLION	1-	5	25	0.875	<.01	22.37	22.10	0.60	7.73	-3.10	19.70	-0.156	0.020	22.04, 22.70*
464		STILLWATER CREEK	1-	5	21	0.881	<.01	9.80	9.60	0.50	11.41	-0.50	24.90	-0.213	0.019	9.66, 9.94*
473	PR10	SUMMIT RANCH	1-	5	23	-0.185	39.77	12.88	12.70	0.30	10.02	-3.00	25.10	0.032	-0.003	12.69, 13.07
489	RH10	TOWER	1-	5	21	-0.357	11.21	19.24	-47.40	80.70	5.64	-3.30	17.00	11.507	-2.040	18.96, 19.52*
491		TRAPPER LAKE	1-	5	21	0.669	0.09	21.38	21.20	0.40	9.64	-4.20	24.10	-0.078	0.008	21.06, 21.70
502	PR10	UNIVERSITY CAMP	1-	5	20	0.868	<.01	24.99	24.70	0.60	7.57	-2.20	21.10	-0.177	0.023	24.63, 25.35
504	PR10	UPPER SAN JUAN	1-	5	20	0.000	100.00	39.90	39.90	0.00	8.30	-1.90	21.20	0.000	0.000	39.33, 40.47
506	RH10	VAIL MOUNTAIN	1-	5	20	0.895	<.01	22.75	22.50	0.50	9.93	-0.40	18.90	-0.306	0.031	22.44, 23.06
507		VALLECITO	1-	5	23	0.901	<.01	28.61	28.50	0.30	10.10	1.10	16.60	-0.183	0.018	28.23, 28.99
511	RH05	W FORK PARACHUTE	1-	5	22	-0.697	0.03	13.76	13.60	0.40	10.57	-3.50	25.70	0.094	-0.009	13.56, 13.96*
521	RH05	WHISKEY CK	1-	5	16	0.895	<.01	28.12	27.80	0.70	10.15	-0.80	22.80	-0.237	0.024	27.73, 28.51
533	PR10	WILLOW CREEK PASS	1-	5	22	-0.244	27.29	14.70	14.60	0.20	7.56	-4.40	25.40	0.009	-0.002	14.48, 14.92
534	RH10	WILLOW PARK	1-	5	17	0.774	0.02	21.66	21.00	1.50	8.23	-1.70	20.20	-0.482	0.058	21.35, 21.97*
537		WOLF CREEK SUMMIT	1-	5	22	0.752	<.01	40.88	40.60	0.60	8.87	0.50	15.60	-0.233	0.026	40.33, 41.43
544	RH10	Z COLO SHOP	1-	5	19	0.361	12.92	99.63	99.60	0.10	22.73	7.70	32.10	-0.043	0.002	98.55, 100.71
545	PR10	Z COLO TEST	1-	5	20	0.000	100.00	100.00	100.00	0.00	-51.30	-51.30	0.00	0.000	0.000	96.79, 103.21

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 38. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN IDAHO (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987 DATE NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
						Ave	Min	Delta	Ave	Min	Delta	a	b	Low	High
428	RH10	SHERWIN	1- 5 24	-0.140	51.27	27.53	25.30	12.00	4.96	-13.80	43.30	0.152	-0.031	27.02	28.04*
437	RH10	SLUG CREEK DIVIOE	1- 5 20	0.085	72.16	17.21	17.20	0.10	10.35	-2.20	24.90	-0.008	0.000	16.96	17.46
443	RH05	SOMSEN RANCH	1- 5 21	0.938	<.01	13.76	13.50	0.40	7.60	-3.90	21.90	-0.135	0.017	13.55	13.97*
446	RH15	SOUTH MTN.	1- 4 15	-0.720	0.24	6.14	-1.90	23.40	12.15	0.10	23.20	14.705	-1.210	6.06	6.22*
454	RH10	SQUAW FLAT	1- 5 23	-0.637	0.10	23.45	23.10	0.50	10.22	-3.90	27.20	0.129	-0.013	23.10	23.80
463	RH10	STICKNEY MILL	1- 5 19	-0.931	<.01	10.78	10.30	1.00	10.33	-4.40	26.80	0.370	-0.036	10.62	10.94*
474	RH15	SUNSET	1- 5 20	-0.938	<.01	38.42	37.40	1.70	10.78	-0.90	25.50	0.669	-0.063	37.88	38.96*
476	RH20	SWEDE PEAK	1- 5 21	0.704	0.03	14.53	14.30	0.50	10.46	-3.10	26.60	-0.153	0.015	14.32	14.74*
493	RH15	TRINITY MTN.	1- 5 21	-0.995	<.01	15.79	-7.10	32.30	-32.68	-51.30	72.70	-15.824	-0.484	15.28	16.30*
509	RH15	VIENNA MINE	1- 5 21	0.866	<.01	24.25	23.90	1.00	8.47	-4.10	23.90	-0.356	0.042	23.88	24.62*
519	RH10	WEST BRANCH	1- 5 20	0.708	0.04	18.03	-4.30	29.90	13.06	-0.90	27.40	-14.735	1.128	17.78	18.28*
524	RH10	WHITE ELEPHANT	1- 5 19	0.030	90.41	9.11	-6.00	28.60	9.92	-3.70	26.10	-0.558	0.056	8.97	9.25*
531	BA0	WILHORSE DIVIOE	1- 5 23	0.691	0.02	16.43	16.00	1.20	11.78	-1.30	27.50	-0.400	0.034	16.20	16.66*
542		Z BOISE SHOP	1- 5 20	0.000	100.00	0.00	0.00	0.00	-45.82	-45.90	0.10	0.000	0.000	0.00	0.00

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 39. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN MONTANA (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							Ave	Min	Delta	Ave	Min	Delta	a	b	Low	High
405	PR10	SAGOLE MTN.	1- 5	20	-0.428	5.97	20.62	20.50	0.20	6.40	-7.70	29.70	0.024	-0.004	20.28	20.96
429	PR10	SHOWER FALLS	1- 5	20	-0.341	14.08	25.97	25.90	0.10	5.87	-5.60	28.80	0.010	-0.002	25.56	26.38
433	PR10	SILVER RUN	1- 5	21	-0.585	0.53	14.80	14.70	0.20	9.63	-5.50	32.30	0.030	-0.004	14.57	15.03
435	PR10	SKALKAHO SUMMIT	1- 5	20	-0.609	0.43	23.58	23.50	0.20	4.65	-6.10	26.70	0.012	-0.004	23.21	23.95
436	RH15	SKYLARK TRAIL	1- 5	21	0.519	1.59	31.73	31.30	0.70	10.15	-1.60	26.30	-0.121	0.012	31.28	32.18
453	PR10	SPUR PARK	1- 5	22	-0.483	2.28	13.71	-5.90	22.70	5.93	-6.60	29.00	2.567	-0.432	13.49	13.93*
458	RH15	STAHL PEAK	1- 5	21	0.297	19.10	40.06	39.70	0.70	6.59	-2.50	24.20	-0.043	0.006	39.48	40.64
482	PR10	TEPEE CREEK	1- 5	20	0.113	63.55	13.26	13.20	0.10	11.19	-0.10	23.70	-0.014	0.001	13.08	13.44
499	PR10	TWELVEMILE CREEK	1- 5	21	0.302	18.27	27.64	27.20	1.00	9.44	-5.10	32.60	-0.084	0.009	27.21	28.07*
500	PR15	TWIN LAKES	1- 5	21	-0.783	<.01	40.92	40.70	0.30	7.95	-4.20	30.10	0.063	-0.008	40.30	41.54
512	PR10	WALDRON	1- 5	22	-0.387	7.54	17.45	17.20	0.40	9.09	-4.70	32.70	0.035	-0.004	17.18	17.72
515	PR10	WARM SPRINGS	1- 5	20	0.563	0.97	22.28	22.20	0.10	1.85	-11.50	33.60	-0.004	0.002	21.88	22.68
522	PR10	WHISKEY CREEK	1- 5	21	-0.614	0.30	14.75	14.60	0.40	7.18	-8.40	33.10	0.038	-0.006	14.50	15.00*
539	PR10	WOOD CREEK	1- 5	20	-0.335	14.92	17.70	17.60	0.10	10.81	-2.30	27.90	0.004	-0.001	17.44	17.96

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.





TABLE 41. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN OREGON (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							Ave	Min	Delta	Ave	Min	Delta	a	b	Low	High
399	RH10	ROCK SPRINGS	1- 5	16	0.057	83.49	10.49	10.40	0.10	15.48	-1.90	31.50	-0.006	0.000	10.34	10.64
404	RH20	SADOLE MOUNTAIN	1- 5	20	-0.833	<.01	83.71	81.60	3.10	11.23	0.50	23.70	1.169	-0.105	82.59	84.83*
407	RH15	SALT CREEK FALLS	1- 5	22	-0.921	<.01	48.10	47.20	1.50	14.63	2.00	24.30	0.859	-0.059	47.48	48.72*
411	RH15	SANTIAM JCT.	1- 5	21	-0.757	<.01	54.12	53.80	0.80	14.22	-2.30	30.10	0.318	-0.022	53.34	54.90
414	RH10	SCHNEIDER MEADOWS	1- 5	19	0.945	<.01	29.32	29.00	0.70	10.65	-3.60	28.00	-0.248	0.023	28.88	29.76
420	RH20	SEINE CREEK	1- 5	21	-0.622	0.25	66.09	65.60	1.00	6.12	-4.90	24.60	0.146	-0.025	65.07	67.11
431	RH10	SILVER CREEK	1- 5	18	-0.129	60.93	18.61	18.40	0.40	14.84	-4.90	33.60	0.023	-0.001	18.32	18.90
434	RH10	SILVIES	1- 5	21	0.608	0.34	22.00	21.90	0.20	12.86	-5.30	25.40	-0.101	0.008	21.66	22.34
441	PR15	SNOW MOUNTAIN	1- 5	20	-0.931	<.01	22.27	22.10	0.40	11.52	-4.50	27.30	0.171	-0.014	21.93	22.61
460	RH10	STARR RIDGE	1- 5	23	0.346	10.58	13.01	12.80	0.40	15.53	-2.40	31.30	-0.070	0.005	12.82	13.20*
465	PR10	STRAWBERRY	1- 5	21	0.282	21.53	12.97	12.70	0.50	15.77	-3.40	29.80	-0.082	0.005	12.78	13.16*
471	PR10	SUMMER RIM	1- 5	21	0.109	63.72	14.26	11.30	29.00	7.20	-8.90	24.00	-0.823	0.114	14.02	14.50*
472	RH15	SUMMIT LAKE	1- 5	21	-0.343	12.76	49.08	48.40	1.10	10.00	-5.60	31.10	0.115	-0.012	48.31	49.85
479	RH15	TAYLOR BUTTE	1- 5	21	-0.732	0.01	11.43	11.30	0.40	14.49	-6.60	36.80	0.123	-0.008	11.25	11.61*
481	RH15	TAYLOR GREEN	1- 5	23	-0.914	<.01	22.63	22.00	1.60	12.07	-1.60	24.50	0.757	-0.063	22.31	22.95*
483	RH15	THREE CREEKS MEADOW	1- 5	17	-0.263	30.71	28.81	27.70	6.80	12.28	-3.50	30.90	0.890	-0.072	28.38	29.24*
485	RH10	TIPTON	1- 5	24	0.693	0.01	18.19	18.00	0.60	13.94	0.00	25.50	-0.213	0.015	17.94	18.44*
536		WOLF C	1- 5	21	-0.404	6.93	20.50	20.30	0.40	20.47	4.10	29.10	0.112	-0.006	20.25	20.75

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.



TABLE 42. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN UTAH (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987		P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
			DATE	NOBS			AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
311	RH10	MIOWAY VALLEY	1- 5	22	-0.567	0.59	23.93	23.80	0.20	11.02	0.00	19.60	0.072	-0.006	23.60	24.26
316	PR10	MONTE CRISTO	1- 5	20	-0.101	67.08	21.74	21.30	0.80	6.17	-5.90	23.20	0.028	-0.004	21.40	22.08*
324	RH10	MOSSBY MTN.	1- 5	21	-0.809	<.01	18.50	18.10	0.60	11.40	1.30	21.20	0.284	-0.025	18.26	18.74*
363	PR10	PARLEY'S SUMMIT	1- 5	20	-0.494	2.66	20.31	20.20	0.20	14.73	2.30	24.80	0.057	-0.004	20.05	20.57
364	PR10	PAYSON R.S.	1- 5	22	-0.605	0.28	19.64	19.50	0.30	11.62	0.60	21.90	0.115	-0.010	19.38	19.90
369	PR10	PICKLE KEG	1- 5	20	-0.207	38.07	18.96	18.00	1.20	9.58	-2.00	21.10	0.089	-0.009	18.69	19.23*
372	RH10	PINE CREEK	1- 5	22	-0.374	8.59	19.42	19.30	0.20	13.30	0.80	22.50	0.051	-0.004	19.16	19.68
392	PR10	RED PINE RIDGE	1- 5	20	0.124	60.12	18.98	18.70	0.40	9.47	-1.70	20.80	-0.015	0.002	18.71	19.25*
398	RH10	ROCK CREEK	1- 5	23	0.454	2.96	14.51	14.00	1.20	7.85	-2.60	20.20	-0.192	0.025	14.30	14.72*
401		ROCKY BASIN	1- 5	22	0.589	0.39	31.36	31.30	0.20	10.76	-0.90	23.10	-0.061	0.006	30.92	31.80
419	PR10	SEELEY CREEK	1- 5	22	0.000	100.00	20.40	20.40	0.00	7.67	-0.10	16.00	0.000	0.000	20.12	20.68
439	PR10	SMITH & MOREHOUSE	1- 5	21	0.246	28.20	18.40	18.30	0.10	10.74	-3.80	27.70	-0.011	0.001	18.12	18.68
461	PR10	STEEL CREEK PARK	1- 5	19	0.000	100.00	22.00	22.00	0.00	8.23	-2.50	18.90	0.000	0.000	21.68	22.32
466	PR10	STRAWBERRY DIVIDE	1- 5	20	-0.818	<.01	16.75	16.50	0.40	14.51	3.70	21.70	0.178	-0.012	16.54	16.96*
484	RH10	TIMPANOGOS DIVIDE	1- 5	20	0.353	12.68	18.92	18.50	0.90	14.26	3.00	21.30	-0.209	0.015	18.68	19.16*
487	PR10	TONY GROVE LAKE	1- 5	20	0.267	25.45	24.92	24.80	0.20	9.97	-0.90	24.00	-0.028	0.003	24.57	25.27
492	PR10	TRIAL LAKE	1- 5	22	0.372	8.86	23.41	23.30	0.20	6.96	-2.50	21.90	-0.035	0.005	23.07	23.75
497	RH10	TROUT CREEK	1- 5	22	-0.714	0.01	16.21	16.00	0.30	11.92	-3.00	26.70	0.102	-0.009	15.97	16.45
508	PR10	VERNON CREEK	1- 5	20	-0.376	10.21	15.18	15.10	0.10	15.13	3.30	23.60	0.029	-0.002	14.99	15.37
518	PR10	WEBSTER FLAT	1- 5	20	0.522	1.82	18.73	18.60	0.20	15.25	6.20	16.00	-0.115	0.007	18.52	18.94
528	PR10	WHITE RIVER #1	1- 5	19	-0.601	0.65	15.51	15.40	0.30	10.71	-2.40	24.40	0.087	-0.009	15.29	15.73
529	PR10	WILOSTOE #3	1- 5	23	-0.610	0.20	19.99	19.80	0.30	12.39	0.70	20.90	0.110	-0.009	19.72	20.26

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

TABLE 43. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN WASHINGTON.

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987 DATE	NOBS	P/T CORRECTION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							Ave	Min	Delta	Ave	Min	Delta	a	b	Low	High
52	RH15	BLEWETT PASS	1- 5	21	0.906	<.01	25.98	25.30	1.40	12.82	0.00	22.90	-0.630	0.049	25.63	26.33*
75	RH15	BUNCHGRASS MOW	1- 5	21	-0.437	4.75	37.37	37.00	0.70	10.09	-0.70	24.30	0.106	-0.010	36.85	37.89
116	PR15	CORRAL PASS	1- 5	19	-0.796	<.01	47.67	47.10	1.00	7.98	-3.30	25.20	0.254	-0.031	46.96	48.38
118	RH15	COUGAR MOUNTAIN	1- 5	19	0.272	25.97	77.23	76.70	1.10	11.35	-0.70	25.90	-0.161	0.014	76.16	78.30
173	RH15	FISH LAKE	1- 5	20	0.862	<.01	50.90	49.90	1.90	6.06	-4.20	24.00	-0.415	0.069	50.13	51.67*
196	RH10	GREEN LAKE	1- 5	18	0.000	100.00	27.90	27.90	0.00	9.43	-3.20	27.30	0.000	0.000	27.49	28.31
201	RH10	GROUSE CAMP	1- 5	23	-0.536	0.83	31.42	31.30	0.20	10.22	-2.50	23.50	0.069	-0.007	30.96	31.88
209	RH20	HARTS PASS	1- 5	20	0.279	23.39	63.62	63.30	0.50	6.68	-4.60	22.30	-0.040	0.007	62.65	64.59
246	RH25	JUNE LAKE	1- 5	22	-0.898	<.01	127.24	101.00	42.70	12.08	0.50	22.90	18.442	-1.526	125.53	128.95*
294	RH25	LYMAN LAKE	1- 5	21	0.708	0.03	78.98	78.70	0.60	9.52	-2.80	26.30	-0.167	0.017	77.83	80.13
314	RH20	MIRROR LAKE	1- 5	19	-0.768	0.01	45.60	45.00	1.10	6.77	-3.50	23.20	0.244	-0.036	44.92	46.28
323	RH20	MORSE LAKE	1- 5	21	0.710	0.03	78.36	77.80	1.80	10.02	-0.50	24.70	-0.556	0.055	77.28	79.44*
353	RH25	OLALLIE MEADOWS	1- 3	6	0.000	100.00	94.60	94.60	0.00	4.53	-1.50	18.00	0.000	0.000	93.26	95.94
358	RH25	PARADISE	1- 5	21	-0.701	0.04	93.14	92.90	0.40	9.00	-2.10	25.30	0.082	-0.009	91.80	94.48
360	RH15	PARK CREEK RIOGE	1- 5	21	0.767	<.01	57.31	56.90	0.90	5.46	-3.40	18.70	-0.182	0.033	56.46	58.16
370	RH15	PIGTAIL PEAK	1- 5	20	-0.832	<.01	51.89	51.00	1.40	8.00	-2.40	24.60	0.406	-0.051	51.14	52.64*
374	RH25	PLAINS OF ABRAHAM	1- 5	21	0.822	<.01	102.38	101.20	3.30	11.34	0.00	21.20	-1.610	0.142	100.99	103.77*
377	RH10	POPE RIOGE	1- 5	20	-0.699	0.06	27.99	27.70	0.60	11.68	-4.00	26.40	0.173	-0.015	27.57	28.41
380	RH25	POTATO HILL	1- 5	19	-0.524	2.13	49.91	49.60	0.50	10.14	-1.40	26.40	0.132	-0.013	49.21	50.61
385		QUARTZ PEAK	1- 5	23	0.922	<.01	31.97	31.30	1.40	12.64	-0.60	25.80	-0.560	0.044	31.53	32.41*
389	RH25	RAINY PASS	1- 5	21	-0.457	3.73	49.65	49.50	0.30	6.09	-3.20	24.50	0.029	-0.005	48.92	50.38
406	PR15	SALMON MEADOWS	3- 5	5	-0.066	91.64	15.06	15.00	0.10	17.76	13.60	8.80	0.019	-0.001	14.93	15.19
412	RH15	SASSE RIOGE	1- 5	22	0.569	0.57	43.39	43.30	0.50	11.25	-1.30	27.80	-0.122	0.011	42.78	44.00
425	RH25	SHEEP CANYON	1- 5	21	-0.691	0.05	110.90	110.70	0.60	11.16	-0.50	22.90	0.189	-0.017	109.37	112.43
448	RH20	SPENCER MEADOW	1- 5	22	-0.022	92.36	77.25	76.50	1.40	16.99	1.70	28.50	0.024	-0.001	76.25	78.25
449		SPIRIT LAKE	1- 5	21	-0.056	80.78	74.50	74.20	0.90	11.98	0.90	22.70	0.019	-0.002	73.51	75.49
459	RH25	STAMPEDE PASS	1- 5	17	0.761	0.03	40.68	37.70	6.20	4.02	-7.10	25.80	-0.827	0.206	40.02	41.34*
462	RH20	STEVENS PASS	1- 5	20	-0.963	<.01	70.06	69.40	1.20	9.70	-2.30	27.40	0.451	-0.046	69.05	71.07
467	RH25	STRAWBERRY LANDING	1- 5	22	-0.882	<.01	77.32	76.80	1.10	9.99	-1.30	22.80	0.496	-0.050	76.23	78.41
475	RH25	SURPRISE LAKES	1- 5	23	-0.834	<.01	69.93	69.60	0.50	15.97	4.10	28.10	0.251	-0.016	69.08	70.78
488	RH15	TOUCHET #2	1- 5	21	0.795	<.01	39.04	38.80	0.50	12.01	-2.90	26.20	-0.185	0.015	38.47	39.61
495	RH15	TROUGH	1- 5	20	0.435	5.52	17.74	16.70	2.70	6.51	-3.80	17.40	-0.486	0.075	17.47	18.01*
505	RH10	UPPER WHEELER	1- 5	22	-0.165	46.37	20.30	20.00	0.50	11.36	-0.40	22.50	0.046	-0.004	20.02	20.58*
527		WHITE PASS E.	1- 5	20	0.456	4.31	31.43	31.00	0.70	9.87	-0.70	24.80	-0.176	0.017	30.99	31.87

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

TABLE 44. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN WYOMING.

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987		P/T CORRECTION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
			DATE	NOBS			AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
10	PR10	BALD MTN.	1- 5	22	-0.363	9.68	21.00	20.90	0.20	3.85	-9.50	29.20	0.011	-0.003	20.64	21.36
14	PR10	BASE CAMP	1- 5	16	0.743	0.09	18.36	17.60	1.70	10.76	-3.40	28.90	-0.514	0.047	18.09	18.63*
17		BATTLE MOUNTAIN	1- 5	22	-0.176	43.45	14.41	14.30	0.20	11.54	-2.40	27.80	0.019	-0.002	14.20	14.62
25	PR10	BEAR TRAP MEADOW	1- 5	22	0.294	18.34	15.72	15.60	0.20	8.15	-2.40	25.70	-0.015	0.002	15.49	15.95
26	PR10	BEARTOOTH LAKE	1- 5	22	0.809	<.01	15.64	15.00	1.00	6.39	-6.10	28.00	-0.174	0.027	15.39	15.89
43	RH10	BIG SANDY OPENING	1- 5	24	0.955	<.01	17.39	16.70	1.80	7.53	-3.70	24.90	-0.551	0.073	17.13	17.65*
50	PR10	BLACKWATER	1- 5	18	0.386	11.34	21.66	21.20	0.60	1.43	-10.40	23.40	-0.018	0.010	21.28	22.04*
53	PR10	BLIND BULL SUM	1- 5	21	-0.768	<.01	19.62	19.50	0.20	8.31	-3.00	24.70	0.050	-0.006	19.33	19.91
57	PR10	BONE SPRINGS DIV	1- 5	19	0.688	0.11	19.98	19.80	0.30	5.02	-6.40	25.90	-0.039	0.008	19.66	20.30
66	PR10	BROOKLYN LAKE	1- 5	21	0.302	18.31	20.20	20.20	0.10	1.76	-10.20	23.50	0.003	0.001	19.85	20.55
76	PR10	BURGESS JUNCTION	1- 5	18	0.641	0.41	16.22	15.80	0.70	0.11	-13.00	27.50	-0.005	0.017	15.92	16.52*
78	PR10	BURROUGHS CREEK	1- 5	21	-0.069	76.49	20.14	-2.10	24.20	7.69	-3.50	26.40	0.370	-0.048	19.84	20.44*
82	PR10	CANYON	1- 5	20	0.728	0.02	14.88	14.50	0.90	7.22	-7.10	32.00	-0.140	0.019	14.64	15.12*
87	RH05	CASPER MTN.	1- 5	22	0.636	0.14	24.48	24.30	0.50	9.40	6.50	8.10	-0.436	0.046	24.20	24.76*
96	PR15	CHRISTINA LAKE	1- 5	20	-0.018	94.04	16.17	-3.90	24.50	9.47	-3.20	24.50	0.207	-0.022	15.93	16.41*
101	PR10	CLOUD PEAK RESERVOIR	1- 5	20	0.115	62.87	20.56	20.30	0.40	2.03	-9.80	26.80	-0.008	0.001	20.21	20.91
117		COTTONWOOD CREEK	1- 5	19	0.382	10.60	21.37	20.90	0.90	9.22	-4.80	26.60	-0.117	0.013	21.04	21.70*
119	RH15	COULTER CREEK	1- 5	21	0.663	0.10	19.56	19.20	1.10	9.28	-4.30	29.50	-0.153	0.016	19.26	19.86*
141	PR10	OINWOODY	1- 5	19	0.161	51.09	12.70	-14.90	32.60	7.70	-5.10	25.50	-1.645	0.214	12.50	12.90*
145	RH10	OLIVIO PEAK	1- 5	23	0.600	0.24	17.85	17.30	1.20	10.63	-0.30	23.50	-0.340	0.032	17.61	18.09*
147	PR10	HOME LAKE	1- 5	22	-0.048	83.27	17.32	17.20	0.20	5.43	-7.00	27.50	0.005	0.000	17.04	17.60
155		EAST RIM OLIVIOE	1- 5	21	0.924	<.01	15.90	15.70	0.40	9.80	-2.30	25.40	-0.161	0.017	15.67	16.13
163	RH10	ELKHART PARK G.S.	1- 5	21	0.595	0.44	17.98	17.10	1.80	8.53	-3.80	24.00	-0.420	0.049	17.71	18.25*
167	PR10	EVENING STAR	1- 5	17	0.598	1.12	24.03	23.70	0.50	6.45	-6.80	27.30	-0.064	0.010	23.64	24.42
194	RH15	GRASSY LAKE	1- 5	21	-0.910	<.01	27.07	26.30	1.20	8.79	-5.20	28.30	0.337	-0.039	26.65	27.49*
200	RH10	GROS VENTRE SUMMIT	1- 5	22	-0.470	2.74	15.19	15.00	0.40	7.88	-5.90	27.70	0.051	-0.006	14.95	15.43
204		HAMS FORK	1- 5	20	0.865	<.01	14.00	13.80	0.50	10.40	-1.50	23.20	-0.179	0.017	13.80	14.20*
207	PR10	HANSEN SAWMILL	1- 5	21	0.406	6.77	14.61	14.30	0.40	8.44	-3.50	28.80	-0.040	0.005	14.39	14.83*
218	PR10	HOBBS PARK	1- 5	19	0.096	69.46	18.07	-3.70	24.40	2.74	-9.30	23.90	-0.264	0.098	17.76	18.38*
237	RH10	INDIAN CREEK	1- 5	20	0.961	<.01	21.70	21.50	0.50	8.17	-3.90	23.60	-0.188	0.023	21.37	22.03
238	PR10	IRISH ROCK	1- 5	10	0.339	33.78	12.02	11.90	0.20	2.80	-6.30	25.60	-0.009	0.003	11.83	12.21
247	PR10	KELLEY R.S.	1- 5	19	0.757	0.01	17.15	17.00	0.50	8.94	-3.00	25.70	-0.122	0.013	16.90	17.40*
248		KENDALL R.S.	1- 5	23	0.946	<.01	16.72	16.50	0.50	8.63	-4.10	26.70	-0.140	0.016	16.47	16.97*
253	PR10	KIRWIN	1- 5	20	-0.464	3.94	14.70	14.60	0.20	6.77	-4.00	24.20	0.023	-0.003	14.48	14.92
264	RH10	LAPRELE CREEK	1- 5	23	0.733	<.01	19.34	16.30	6.30	7.60	-6.10	29.50	-1.362	0.180	19.03	19.65*
269	RH10	LEWIS LAKE OLIVIOE	1- 5	22	0.908	<.01	25.80	25.50	0.70	9.27	-3.80	26.40	-0.230	0.025	25.41	26.19*
277	PR10	LITTLE WARM	1- 5	22	0.013	95.30	17.83	17.50	0.60	5.80	-8.20	28.60	-0.004	0.000	17.53	18.13*
288	PR10	LOST CREEK	1- 5	20	-0.036	87.98	18.48	18.40	0.20	9.81	-2.00	28.00	0.003	0.000	18.22	18.74
302	PR10	MARQUETTE	1- 5	19	0.593	0.74	18.47	18.20	0.40	9.27	-5.10	27.10	-0.073	0.008	18.18	18.76
310	PR10	MIDDLE POWDER	1- 5	22	0.325	13.99	18.40	18.30	0.20	10.27	-0.60	29.10	-0.014	0.002	18.15	18.65
342		NEW FORK LAKE	1- 5	22	0.853	<.01	16.81	16.10	1.80	8.59	-3.10	25.40	-0.568	0.066	16.56	17.06*
348	PR10	NORTH FRENCH CREEK	1- 5	22	0.605	0.28	22.31	22.20	0.30	5.61	-5.70	24.00	-0.042	0.008	21.96	22.66
351	PR10	NOWOOD	1- 5	19	-0.043	86.06	10.48	10.20	0.50	8.68	-3.20	27.80	0.011	-0.001	10.33	10.63*
354	RH15	OLD BATTLE	1- 5	22	-0.599	0.32	30.75	30.50	0.60	6.32	-4.30	21.90	0.096	-0.015	30.28	31.22
355	PR10	OWL CREEK	1- 5	18	-0.109	66.82	12.11	11.70	0.50	8.14	-5.30	28.70	0.014	-0.002	11.92	12.30*
362	PR10	PARKER PEAK	1- 5	21	0.810	<.01	16.88	16.60	0.50	4.61	-7.90	25.30	-0.083	0.017	16.60	17.16*
367	PR10	PHILLIPS BENCH	1- 5	21	0.488	2.46	27.82	27.50	0.60	7.23	-4.80	26.70	-0.089	0.012	27.39	28.25
381	PR10	POWDER RIVER PASS	1- 5	21	0.429	5.21	16.19	15.80	0.50	2.23	-8.10	22.70	-0.024	0.011	15.92	16.46*
394	RH10	RENO HILL	1- 5	20	0.813	<.01	23.48	22.90	1.50	10.45	-2.70	28.30	-0.603	0.058	23.14	23.82*
408	PR10	SALT RIVER SUMMIT	1- 5	20	0.000	100.00	15.00	15.00	0.00	7.29	-4.70	25.20	0.000	0.000	14.77	15.23

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

TABLE 44. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN WYOMING (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987		P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
			DATE	NOBS			AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
409	RH10	SAND LAKE	1- 5	21	0.619	0.27	23.97	23.70	0.60	4.91	-6.00	22.40	-0.068	0.013	23.59	24.35
410		SANOSTONE RS	1- 5	25	-0.810	<.01	16.00	15.80	0.40	11.19	-1.30	23.60	0.153	-0.014	15.77	16.23
427	PR10	SHELL CREEK	1- 5	20	-0.141	55.20	16.80	16.70	0.20	0.38	-11.20	27.70	0.005	-0.001	16.50	17.10
440	RH10	SNIOER BASIN	1- 5	21	0.975	<.01	28.15	13.70	72.30	25.44	-4.10	99.90	-19.836	0.780	27.28	29.02*
445	PR10	SOUTH BRUSH CREEK	1- 5	20	0.209	37.71	14.62	14.50	0.20	9.73	-3.30	25.70	-0.017	0.002	14.40	14.84
447		SOUTH PASS	1- 5	22	0.029	89.81	17.59	-3.70	24.60	9.62	-4.50	26.90	-0.298	0.031	17.32	17.86*
451	PR10	SPRING CREEK DIVIOE	1- 5	23	-0.187	39.25	21.11	21.00	0.20	8.90	-2.80	21.80	0.018	-0.002	20.80	21.42
456	PR10	ST. LAWRENCE	1- 5	20	-0.317	17.35	15.94	-2.80	20.90	9.17	-5.50	29.90	2.066	-0.226	15.69	16.19*
457	PR10	ST. LAWRENCE ALT	1- 5	21	-0.385	8.51	14.29	-2.30	18.40	8.50	-4.50	27.40	2.139	-0.252	14.07	14.51*
469	PR10	SUCKER CREEK	1- 5	23	0.162	46.06	18.79	18.70	0.30	6.90	-5.90	28.40	-0.016	0.002	18.49	19.09
477	PR10	SYLVAN LAKE	1- 5	23	-0.405	5.51	20.74	20.60	0.40	4.94	-10.00	31.70	0.030	-0.005	20.38	21.10
486	RH10	TOGWOTEE PASS	1- 5	22	0.323	14.24	26.28	26.20	0.20	3.51	-8.00	25.80	-0.010	0.002	25.85	26.71
490	PR10	TOWNSEND CREEK	1- 5	21	0.348	12.22	18.80	-1.70	47.40	10.13	-5.70	32.40	-3.132	0.309	18.51	19.09*
494		TRIPLE PEAK	1- 5	23	0.887	<.01	23.59	22.60	1.80	8.52	-3.40	23.90	-0.686	0.081	23.24	23.94*
496	PR10	TROUT CK	1- 5	21	0.576	0.63	13.88	13.30	0.80	8.55	-4.90	28.40	-0.121	0.014	13.67	14.09*
501	RH15	TWO OCEAN PLATEAU	1- 5	20	0.775	<.01	24.77	24.60	0.40	6.20	-9.50	30.30	-0.067	0.011	24.35	25.19
516	PR10	WARREN PEAK	1- 5	24	-0.080	70.91	18.19	18.10	0.10	9.75	-0.10	26.50	0.005	0.000	17.94	18.44
517	RH10	WEBBER SPRINGS	1- 5	20	0.947	<.01	22.88	22.30	1.40	9.36	-1.00	23.80	-0.494	0.052	22.56	23.20*
532	RH15	WILLOW CREEK	1- 5	25	0.953	<.01	28.82	28.40	1.00	10.08	-1.70	24.70	-0.344	0.034	28.41	29.23*
535	RH05	WINDY PEAK	1- 5	20	0.859	<.01	24.07	23.80	0.50	11.75	-2.00	28.30	-0.186	0.015	23.73	24.41
538	PR10	WOLVERINE	1- 5	23	0.833	<.01	15.73	15.30	0.80	9.27	-4.50	30.10	-0.182	0.020	15.49	15.97*
552		Z WYOMING	1- 5	21	0.000	100.00	50.00	50.00	0.00	23.12	21.30	4.40	0.000	0.000	49.70	50.30

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

TABLE 45. PRECIPITATION-TEMPERATURE 1987 FLUTTER STUDY STATISTICS FOR SNOTEL SITES IN UNKNOWN STATES.

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	JUNE 1987 DATE	NOBS	P/T CORRE- LATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
							AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
65		BRIGHTON	1- 5	21	0.770	<.01	27.53	27.30	0.40	9.95	-0.30	20.30	-0.141	0.014	27.15	27.91
69		BRUNDAGE RESERVOIR	1- 5	21	0.879	<.01	28.22	28.00	0.50	11.20	-1.90	26.60	-0.215	0.019	27.82	28.62
103		CLOVER VALLEY	1- 5	15	-0.230	40.90	21.59	21.20	0.50	27.47	10.80	28.70	0.071	-0.003	21.36	21.82*
124		CROSHO	1- 5	22	0.541	0.92	17.35	17.10	0.60	9.73	-1.50	23.30	-0.151	0.015	17.10	17.60*
154	DUM3	EAGLEHEAD	1- 5	21	0.000	100.00	0.00	0.00	0.00	-0.77	-13.20	23.80	0.000	0.000	0.00	0.00
159	RH10	EILERTSON MEADOWS	1- 5	21	0.921	<.01	20.12	19.40	1.30	10.58	-2.60	25.50	-0.519	0.049	19.83	20.41*
202	PR10	HAGAN'S MEADOW	1- 5	21	-0.142	53.87	14.06	13.90	0.20	12.62	-2.50	23.40	0.019	-0.001	13.86	14.26
287	PR15	LOOMIS PARK	1- 5	22	0.636	0.14	19.45	19.30	0.30	7.94	-3.30	25.90	-0.053	0.007	19.16	19.74
308		MESA LAKES	1- 5	21	0.390	8.03	26.98	26.80	0.40	8.91	-3.10	21.10	-0.067	0.007	26.58	27.38
337	PR10	N FK ELK CREEK	1- 5	20	-0.661	0.15	13.95	13.80	0.30	14.94	3.30	28.70	0.113	-0.007	13.78	14.12
387		RABBIT EARS	1- 5	22	-0.843	<.01	27.61	27.50	0.20	8.35	-2.50	22.50	0.057	-0.007	27.21	28.01
395		RIPPLE CREEK	1- 5	23	0.749	<.01	29.99	29.90	0.20	9.13	-2.80	25.70	-0.054	0.006	29.55	30.43
422	RH15	SEVENMILE MARSH	1- 5	22	-0.921	<.01	37.61	37.10	1.20	13.95	-3.40	27.60	0.652	-0.046	37.05	38.17*
452		SPUD MOUNTAIN	1- 5	20	0.757	0.01	39.89	39.30	1.30	8.51	-0.20	18.40	-0.317	0.037	39.34	40.44*
468		STUMP LAKES	1- 5	21	0.461	3.52	36.85	36.60	0.60	-51.14	-51.30	2.10	9.240	0.181	35.67	38.03
503		UPPER RIO GRANOE	1- 5	25	0.862	<.01	20.40	19.90	1.20	9.19	-2.30	23.60	-0.378	0.041	20.11	20.69*
523		WHISKEY PARK	1- 5	22	0.914	<.01	22.37	22.10	0.60	8.58	-2.00	21.90	-0.229	0.026	22.05	22.69*
550		Z STROMQUIST BENCH	1- 5	21	0.000	100.00	0.00	0.00	0.00	17.96	7.10	23.20	0.000	0.000	0.00	0.00
551		Z STROMQUIST TEST	1- 5	24	0.000	100.00	0.00	0.00	0.00	17.95	6.50	24.60	0.000	0.000	0.00	0.00
558		ZZZ LAPOINT	1- 5	24	0.000	100.00	0.00	0.00	0.00	65.07	45.30	37.00	0.000	0.000	0.00	0.00

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

Table 46. Sites selected as candidates for transducer replacement during 1987.

SITE NO	SNOTEL STATION NAME	SITE NO	SNOTEL STATION NAME
ARIZONA		OREGON (CONTINUED)	
114	CORONADO TRAIL	174	FISH LK.
470	SUGAR LOAF	216	HIGH RIDGE
COLORADO		229	HYATT PRAIRIE
79	BUTTE	251	KING MOUNTAIN
106	COLUMBINE	276	LITTLE MEADOWS
107	COLUMBINE PASS	388	RAILROAD OVERPASS
186	GALLEGOS PEAK	404	SADDLE MOUNTAIN
273	LILY POND	407	SALT CREEK FALLS
295	LYNX PASS	414	SCHNEIDER MEADOWS
304	MC CLURE PASS	481	TAYLOR GREEN
338	NAST LAKE	UTAH	
334	WILLOW PARK	29	BEAVER DAMS
IDAHO		81	CAMP JACKSON
12	BANNER SUMMIT	170	FARNSWORTH LAKE
192	GRAHAM GUARD STATION	265	LASAL MOUNTAIN
319	MOORES CREEK SUMMIT	271	LIGHTNING LAKE
325	MOSQUITO RIDGE	324	MOSBY MTN.
424	SHANGHI SUMMIT	WASHINGTON	
463	STICKNEY MILL	52	BLEWETT PASS
474	SUNSET	116	CORRAL PASS
509	VIENNA MINE	173	FISH LAKE
MONTANA		314	MIRROR LAKE
153	DUPUYER CREEK	323	MORSE LAKE
NEVADA		370	PIGTAIL PEAK
157	EBBETTS PASS	374	PLAINS OF ABRAHAM
333	MT. ROSE	385	QUARTZ PEAK
376	POLE CREEK R. S.	459	STAMPEDE PASS
444	SONORA PASS	462	STEVENS PASS
455	SQUAW VALLEY G. C.	467	STRAWBERRY LANDING
478	TAHOE CITY CROSS	WYOMING	
514	WARD MOUNTAIN	14	BASE CAMP
520	WET MEADOWS	26	BEARTOOTH LAKE
OREGON		43	BIG SANDY OPENING
4	ARBUCKLE MTN	194	GRASSY LAKE
44	BIGELOW CAMP	248	KENDALL R. S.
45	BILLIE CREEK DIVIDE	269	LEWIS LAKE DIVIDE
60	BOURNE	342	NEW FORK LAKE
131	DALY LAKE	394	RENO HILL
138	DIAMOND LAKE	494	TRIPLE PEAK
172	FISH CREEK	517	WEBBER SPRINGS
		532	WILLOW CREEK
		538	WOLVERINE

TABLE 47. PRECIPITATION-TEMPERATURE FLUTTER STUDY STATISTICS FOR SELECTED SNOTEL SITES IN OCTOBER 1987.

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	OCTOBER 1987		P/T CORRELATION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
			DATE	NOBS			AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
ARIZONA																
14	RH10	CORONA00 TRAIL	2-12	36	0.803	<.01	0.19	0.00	0.50	10.39	-2.30	26.30	-0.155	0.015	0.19,	0.19*
59	RH10	SUGAR LOAF	2-12	41	-0.484	0.13	1.50	-0.90	8.60	-2.27	-45.60	75.30	-0.119	-0.054	1.45,	1.55*
COLORADO																
11	RH10	BUTTE	2-12	43	0.210	17.68	0.03	-0.10	0.20	7.48	-2.10	22.10	-0.023	0.003	0.03,	0.03*
13	RH10	COLUMBINE	2-12	36	0.984	<.01	0.38	-0.20	1.30	13.25	-5.40	42.20	-0.360	0.027	0.37,	0.39*
24	PR10	GALLEGOS PEAK	2-12	32	0.123	50.11	-2.20	-27.80	28.10	7.35	-0.90	17.60	-1.099	0.150	-2.17,	-2.23*
34	RH10	LILY POND	2-12	41	0.680	<.01	0.03	-0.40	1.20	8.28	-1.40	20.00	-0.225	0.028	0.03,	0.03*
36	PR10	LYNX PASS	2-12	42	-0.516	0.04	-0.16	-0.60	0.80	7.65	-8.00	27.20	0.085	-0.011	-0.16,	-0.16*
37	RH10	MC CLURE PASS	2-12	35	0.964	<.01	0.70	-0.10	2.00	10.97	2.80	18.70	-1.210	0.110	0.69,	0.71*
43		NAST LAKE	2-12	45	0.970	<.01	0.70	-0.20	1.80	7.22	-6.40	29.40	-0.390	0.054	0.69,	0.71*
IDAH0																
2	RH10	BANNER SUMMIT	2-12	39	0.772	<.01	0.16	-0.30	0.70	8.79	-6.80	30.30	-0.137	0.016	0.16,	0.16*
25	RH10	GRAHAM GUARD STA.	2-12	35	0.906	<.01	2.78	-0.30	6.10	9.37	-10.70	36.90	-1.967	0.210	2.73,	2.83*
39	RH10	MOORES CREEK SUMMIT	2-12	35	0.886	<.01	0.11	0.00	0.40	11.46	-0.10	24.10	-0.084	0.017	0.10,	0.12*
42	RH15	MOSQUITO RIDGE	2-12	32	-0.655	<.01	0.00	-0.40	0.80	11.48	1.20	21.00	0.313	-0.027	0.00,	0.00*
53	RH15	SHANGHI SUMMIT	2-12	40	-0.676	<.01	-0.02	-0.10	0.10	11.27	0.20	24.20	0.051	-0.005	-0.02,	-0.02*
57	RH10	STICKNEY MILL	2-12	34	0.612	0.01	-0.01	-0.30	0.70	8.88	-8.40	31.00	-0.123	0.014	-0.01,	-0.01*
60	RH15	SUNSET	2-12	37	0.119	48.31	1.09	-0.40	4.00	10.04	-1.20	24.20	-0.368	0.037	1.07,	1.11*
64		VIENNA	2-12	35	0.321	6.02	0.00	-0.10	0.20	8.99	-1.00	21.10	-0.019	0.002	0.00,	0.00*
MONTANA																
18		OUPUYER CREEK	2-12	43	0.650	<.01	0.07	0.00	0.40	7.56	-8.70	29.10	-0.080	0.011	0.07,	0.07*
OREGON																
1	RH10	ARBuckle MTN	2-12	38	0.304	6.36	0.02	-0.10	0.20	9.34	-23.10	44.20	-0.024	0.002	0.02,	0.02*
7	RH15	BIGEL0W CAMP	2-12	36	0.151	37.89	0.04	0.00	0.20	16.39	10.10	15.30	-0.030	0.002	0.04,	0.04*
8	RH15	BILLIE CREEK DIVIOE	2-12	40	-0.516	0.06	0.13	-1.00	14.00	13.35	-7.20	37.50	1.750	-0.131	0.13,	0.13*
10	RH10	BOURNE	2-12	28	-0.771	<.01	-0.05	-0.50	0.70	13.29	4.50	17.90	0.441	-0.033	-0.05,	-0.05*
16	RH20	DALY LAKE	2-12	39	-0.871	<.01	0.00	-0.80	1.40	17.35	9.30	20.10	1.203	-0.069	0.00,	0.00*
17	RH15	DIAMONO LAKE	2-12	42	0.900	<.01	0.34	0.00	0.90	13.33	2.60	22.80	-0.517	0.039	0.34,	0.34*
21	RH15	FISH CREEK	2-12	39	0.721	<.01	0.15	0.00	0.40	10.75	2.30	17.60	-0.248	0.023	0.15,	0.15*
23	RH15	FISH LK.	2-12	40	0.881	<.01	0.21	0.00	0.60	14.31	3.40	26.00	-0.300	0.021	0.21,	0.21*
27	RH15	HIGH RIDGE	2-12	39	0.821	<.01	0.08	-0.40	1.10	18.41	7.60	19.70	-0.945	0.052	0.08,	0.08*
28	RH10	HYATT PRAIRIE	2-12	34	0.779	<.01	0.48	-0.20	2.50	14.18	5.20	21.40	-1.337	0.094	0.47,	0.49*
30	RH15	KING MOUNTAIN	2-12	33	0.919	<.01	0.33	-0.70	3.60	17.76	9.90	18.30	-3.189	0.180	0.33,	0.33*
35	RH15	LITTLE MEADOWS	2-12	41	-0.763	<.01	-0.13	-0.50	0.60	14.89	6.70	19.50	0.426	-0.029	-0.13,	-0.13*
47	RH15	RAILROAD OVERPASS	2-12	34	-0.232	18.62	1.42	-0.70	46.80	16.87	5.60	29.80	4.498	-0.267	1.40,	1.44*
49	RH20	SADOLE MOUNTAIN	2-12	42	-0.118	45.67	2.09	-0.20	88.80	14.70	8.40	16.70	5.762	-0.392	2.07,	2.11*
50	RH15	SALT CREEK FALLS	2-12	41	-0.249	11.67	3.36	-30.00	86.80	13.39	-15.00	44.80	4.942	-0.369	3.30,	3.42*
51	RH10	SCHNEIDER MEADOWS	2-12	41	-0.139	38.44	0.87	0.00	32.00	10.93	-5.00	30.90	0.900	-0.082	0.86,	0.88*
61	RH15	TAYLOR GREEN	2-12	39	-0.113	49.16	0.34	-1.40	27.00	13.95	1.20	24.20	1.101	-0.079	0.34,	0.34*
UTAH																
5	PR10	BEAVER DAMS	2-12	44	0.856	<.01	0.32	-0.30	1.30	12.22	2.10	19.70	-0.721	0.059	0.32,	0.32*
12		CAMP JACKSON	2-12	44	0.917	<.01	0.37	0.10	0.60	13.10	5.10	15.10	-0.608	0.046	0.37,	0.37*
20	RH10	FARNSWORTH LAKE	2-12	37	0.856	<.01	0.43	-0.10	1.20	10.67	3.20	14.60	-0.802	0.075	0.42,	0.44*
31	RH10	LASAL MOUNTAIN	2-12	25	0.786	<.01	0.09	-0.10	0.30	10.76	3.30	16.30	-0.142	0.013	0.09,	0.09*
33	UT10	LIGHTNING LAKE	2-12	40	0.598	<.01	0.71	-0.70	3.70	6.40	-5.70	23.60	-0.681	0.106	0.70,	0.72*
41	RH10	MOSBY MTN.	2-12	43	-0.761	<.01	-0.11	-0.40	0.40	8.21	-1.30	18.70	0.142	-0.018	-0.11,	-0.11*

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

TABLE 47. PRECIPITATION-TEMPERATURE FLUTTER STUDY STATISTICS FOR SELECTED SNOTEL SITES IN OCTOBER 1987 (CONTINUED).

SITE NO	SENSOR TYPE	SNOTEL STATION NAME	OCTOBER 1987		P/T CORRECTION (R)	RANDOM PROB (PCT)	RANGE OF READINGS FOR ZERO PRECIP (INCHES)			TEMPERATURE RANGE (DEGREES C)			TEMPERATURE CORRECTION EQUATION (c = a + bT)		SPECIFICATION ERROR BAND	
			DATE	NOBS			AVE	MIN	DELTA	AVE	MIN	DELTA	a	b	LOW	HIGH
WASHINGTON																
9	RH15	BLEWETT PASS	2-12	38	-0.332	4.14	1.84	-0.60	70.00	11.62	0.00	22.90	7.966	-0.685	1.81	1.87*
15	PR15	CORRAL PASS	2-12	39	-0.275	9.06	0.07	0.00	0.30	11.24	3.30	16.90	0.062	-0.006	0.07	0.07*
22	RH15	FISH LAKE	2-12	30	0.917	<.01	0.14	-0.10	0.70	11.01	-0.90	24.70	-0.287	0.026	0.14	0.14*
38	RH20	MIRROR LAKE	6-12	23	0.157	47.52	10.42	-21.10	92.80	7.42	-2.50	23.80	-4.449	0.599	10.27	10.57*
40	RH20	MORSE LAKE	5-12	24	0.359	8.46	28.08	0.00	61.90	11.99	-1.20	24.60	-18.471	1.541	27.69	28.47*
45	RH15	PIGTAIL PEAK	2-12	40	0.194	22.92	1.55	-0.30	56.10	9.69	0.90	18.90	-3.384	0.349	1.53	1.57*
46	RH25	PLAINS OF ABRAHAM	2-12	43	0.142	36.46	2.63	0.00	110.00	14.07	8.00	13.30	-8.733	0.620	2.60	2.66*
55	RH25	STAMPEDE PASS	2-12	36	-0.040	81.71	-0.45	-14.70	14.90	11.65	4.50	17.00	0.255	-0.022	-0.44	-0.46*
56	RH20	STEVENS PASS	2-12	35	-0.036	83.93	1.88	-0.90	75.20	10.25	1.50	20.10	0.836	-0.082	1.86	1.90*
58		STRAWBERRY L	2-12	43	0.165	29.04	1.45	-1.20	80.90	-11.30	-20.00	17.60	4.547	0.403	1.42	1.48*
WYOMING																
3	PR10	BASE CAMP	2-12	38	0.856	<.01	0.36	-0.10	1.20	7.15	-7.10	30.30	-0.305	0.043	0.35	0.37*
4	PR10	BEARTOOTH LAKE	2-12	40	0.735	<.01	0.04	0.00	0.20	-1.69	-18.60	29.70	0.008	0.006	0.04	0.04*
6	RH10	BIG SANDY OPENING	2-12	44	0.951	<.01	0.60	0.00	1.60	5.39	-8.40	26.30	-0.337	0.062	0.59	0.61*
26	RH15	GRASSY LAKE	2-12	39	-0.891	<.01	-0.22	-0.80	0.90	5.77	-11.40	32.20	0.160	-0.027	-0.22	-0.22*
29		KENDALL R.S.	2-12	39	0.926	<.01	0.12	-0.10	0.50	5.56	-9.10	31.30	-0.095	0.016	0.12	0.12*
32	RH10	LEWIS LAKE DIVIDE	2-12	42	0.763	<.01	0.11	-0.10	0.50	9.48	-6.50	29.60	-0.142	0.015	0.11	0.11*
44		NEW FORK LAKE	2-12	41	0.702	<.01	0.04	0.00	0.20	6.22	-7.70	28.50	-0.038	0.006	0.04	0.04*
48	RH10	RENO HILL	2-12	38	0.437	0.61	-0.49	-5.00	10.30	-1.92	-23.60	44.00	0.188	0.099	-0.48	-0.50*
62		TRIPLE PEAK	2-12	39	0.829	<.01	0.23	0.00	0.60	6.35	-8.80	25.90	-0.154	0.025	0.23	0.23*
65	RH10	WEBBER SPRINGS	2-12	39	0.777	<.01	0.22	0.00	0.70	7.84	-6.30	27.10	-0.189	0.024	0.22	0.22*
67	RH15	WILLOW CREEK	2-12	41	0.030	85.08	2.80	-6.00	46.10	9.90	-0.50	24.20	-0.516	0.052	2.76	2.84*
68	PR10	WOLVERINE	2-11	38	0.554	0.03	0.18	0.00	0.70	6.09	-12.30	34.60	-0.082	0.013	0.18	0.18*

\* INDICATES THAT ONE OR MORE MEASURED PRECIPITATION DATA VALUES FELL OUTSIDE THE SPECIFICATION ERROR BAND.

## Section II Analysis of Reasonable Maximum and Reasonable Minimum Methods

The objective of this phase of the study was to compare the different methods of calculating the reasonable maximum and minimum values reported by the different forecast centers. Seven forecast stations were selected for evaluation and the work has begun. The methods identified for evaluation were:

- A. Fort Worth RFC method. This is essentially a standard multiple regression technique calculating the reasonable maximum and minimum as the 90 percent confidence band for a particular estimate; i.e.,

$$\text{Reasonable Maximum} = Y_{\text{est}} + t_{(90,df)} * SE * \text{SQRT}(1 + 1/n + X'CX)$$

$$\text{Reasonable Minimum} = Y_{\text{est}} - t_{(90,df)} * SE * \text{SQRT}(1 + 1/n + X'CX)$$

- B. Portland RFC method. Regression method based on a single equation derived from composite variables indexing fall precipitation, spring precipitation, and antecedent moisture. Values needed for the index variables that are not available at the time of forecast are estimated from the long time average values of the respective variates. The reasonable maximum and minimum are the 80 percent confidence band estimated about a particular point. If the Standard Error of the estimating equation is not available, it is estimated by using values from a past analysis of forecast errors at the site (FEARS Analysis).
- C. Salt Lake City RFC method. Regression method used for estimating the most probable forecast value but the reasonable maximum and minimum are based on an analysis of runoff indexed to antecedent snow and precipitation as it accumulates during the forecast season.
- D. Kansas City RFC method. Regression method using a single index parameter composed of weighted monthly hydrologic variables such as precipitation, snow water equivalent, and runoff. The reasonable maximum and minimum adjustments are determined for each month by partitioning the variables of which the index parameter is composed into its known and unknown or future elements, calculating the index parameter for the entire historical period as partitioned above, sorting the resulting indecies in descending order, and then selecting the 90 and 10 percent decile values as the adjustments for the reasonable maximum and minimum respectively.
- E. SCS FEARS method. Determine reasonable maximum and minimum based on an analysis of past forecast errors. Essentially uses the 10 and 90 percent decile of the average forecast error to determine the reasonable maximum and minimum. In particular, a normal distribution is fit to the forecast errors with the 50 percent value adjusted to zero, thus shifting the 10 and 90 percent exceedence values. These are then used to adjust the most probable forecast value to obtain the reasonable maximum and minimum.

Much of the data for the seven basins has been downloaded to our VAX and evaluation of the data for the American Fork River near American Fork, Utah was completed. The results obtained for the American Fork River are tabulated in

Tables 48-51. The criteria for comparison include the Nash-Sudcliff coefficient of efficiency, Ce, the coefficient of determination, RSQ, the Standard Error, SE, of the estimating equation, the adjustment factors for calculating the reasonable maximum and minimum estimates, the probability,  $P_t$ , of the confidence interval represented by the reasonable maximum and minimum estimates, and the 1983 forecast values for the most probable, reasonable maximum and reasonable minimum. The data used for the development of the predicting equations and for all subsequent comparisons was for the water years 1961-1983.

Table 48. Comparison of different forecast center methods for calculating the reasonable maximum and reasonable minimum values for the American Fork River basin January forecast.

Statistic	Reference l var	Ft. Worth Method	Portland Method	SLC Method	KC Method	SCS FEARS Method
Se	15.802	15.586	23.819	19.527	12.423	NA
df	21	20	20	19	21	
Ce	.040	.111	-5.18	-.325	.407	
RSQ	.040	.111	.057	.047	.407	
Rmax Adj	+21.36	+21.10	+31.19	+15.46	+8.54	
Rmin Adj	-21.36	-21.10	-31.19	-16.61	-8.83	
Prmax	90%	90%	89.3%	77.6%	74.6%	
Prmin	10%	10%	10.7%	20.8%	24.7%	
1983 Est.	40.62	54.67	67.99	51.83	49.92	
1983 Rmax	61.98	75.77	99.18	67.29	58.47	
1983 Rmin	19.26	33.57	36.80	35.22	41.10	

Table 49. Comparison of different forecast center methods for calculating the reasonable maximum and reasonable minimum values for the American Fork River basin February forecast.

Statistic	Reference l var	Ft. Worth Method	Portland Method	SLC Method	KC Method	SCS FEARS Method
Se	11.916	12.038	12.902	12.804	12.42	13.290
df	21	20	20	19	21	21
Ce	.455	.470	.391	.430	.407	.322
RSQ	.455	.470	.470	.432	.407	.444
Rmax Adj	+16.10	+16.29	+16.90	+12.61	+11.76	+15.31
Rmin Adj	-16.10	-16.29	-16.90	-13.42	-12.25	-15.31
Prmax	90%	90%	89.3%	82.6%	81.8%	86.4%
Prmin	10%	10%	10.7%	15.9%	17.3%	13.6%
1983 Est.	43.30	50.09	56.23	44.38	51.28	56.23
1983 Rmax	59.40	66.38	73.13	56.99	63.03	71.54
1983 Rmin	27.20	33.80	39.33	30.96	39.03	40.92

Table 50. Comparison of different forecast center methods for calculating the reasonable maximum and reasonable minimum values for the American Fork River basin March forecast.

Statistic	Reference l var	Ft. Worth Method	Portland Method	SLC Method	KC Method	SCS FEARS Method
Se	10.500	10.383	10.737	11.464	12.423	11.390
df	21	20	20	19	21	21
Ce	.577	.606	.578	.543	.407	.502
RSQ	.577	.606	.606	.570	.407	.666
Rmax Adj	+14.19	+14.05	+14.06	+10.16	+12.57	+11.24
Rmin Adj	-14.19	-14.05	-14.06	-10.69	-14.76	-11.20
Prmax	90%	90%	89.3%	80.2%	83.3%	83.3%
Prmin	10%	10%	10.7%	18.6%	12.9%	16.8%
1983 Est.	43.10	52.41	55.09	43.66	52.14	55.09
1983 Rmax	57.29	66.46	69.15	53.82	64.71	66.33
1983 Rmin	28.91	38.36	41.03	32.97	37.38	43.89

Table 51. Comparison of different forecast center methods for calculating the reasonable maximum and reasonable minimum values for the American Fork River basin April forecast.

Statistic	Reference l var	Ft. Worth Method	Portland Method	SLC Method	KC Method	SCS FEARS Method
Se	7.435	7.027	7.038	9.669	12.423	9.896
df	21	20	20	19	21	21
Ce	.788	.819	.819	.675	.407	.624
RSQ	.788	.819	.819	.774	.407	.762
Rmax Adj	+10.05	+9.51	+9.22	+7.64	+13.15	+9.67
Rmin Adj	-10.05	-9.51	-9.22	-7.87	-16.3	-9.67
Prmax	90%	90%	89.3%	77.6%	84.4%	82.5%
Prmin	10%	10%	10.7%	21.8%	10.6%	17.5%
1983 Est.	49.78	59.28	60.22	46.91	53.27	60.22
1983 Rmax	59.83	68.79	69.44	54.55	66.42	69.89
1983 Rmin	39.73	50.28	51.00	39.04	36.91	50.55

### Section III      Instrumentation Study

Continuation of the Upper Sheep study on the Reynolds Creek Experimental Watershed has provided the opportunity to monitor the operation of several types of climatological field sensors. Some of the sensors have been in continuous operation for over four years. Comments regarding sensor reliability and data quality are noted below.

#### A.    Soil Moisture

The gypsum soil moisture blocks have continued to provide reliable gross indication of soil moisture for the fourth year without any problems.

#### B.    Humidity

The Texas Electronics model TH-2013 humidity sensor continues to provide high quality data without any failures for the fourth year. Calibration is checked periodically and has continually been within specifications.

#### C.    Wind Run

The Belfort #5-349C-5 anemometer has performed well since the modification to the switching system last year.

#### D.    Pressure Transducer

Thirty-one of the 36 Druck model PDCR 10/D pressure transducers installed in piezometer tubes have performed well. Five transducers had to be replaced because of damage apparently caused by lightning. Approximately one-third of the transducers have been in use four years, one-third for three years, and one-third for two years.

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